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June 28, 1915

THE

RADICAL THEORY

IN

CHEMISTRY.

BY

JOHN JOSEPH GRIFFIN, F.C.S.,

HONORARY MEMBER OF THE PHILOSOPHICAL SOCIETY OF GLASGOW.

[illegible]

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1-3 1916

PREFACE.

In this work I propose to prove that the laws of Organic Chemistry are as simple and orderly as the laws of Inorganic Chemistry, and that the confusion which prevails in the former is attributable in no degree to irregularity in organic compounds, but to a disregard of the true laws of the science and a devotion to false hypotheses.

The work includes a critical inquiry into the authority and importance of the doctrines which are commonly accepted by chemists as sound, and of others, which I recommend for adoption, as better proved and of more universal application.

I cannot enumerate these new doctrines without encroaching upon the Table of Contents, but I may specify a few examples:—

- A new theory of the constitution and atomic measure of gaseous salts and radicals.
- A method of determining the atomic measures and specific gravities of compound gases, from their formulæ alone.
- A theory of the origin and metamorphoses of organic radicals.
- A theory of vice-radicals.
- A theory of salts, free from acids and bases.
- A consistent theory of ammoniums and amidogens, and of the salts which are formed by those radicals.
- A theory of anhydrides, explanatory of the constitution of those salts in which both radicals are acid radicals.
- An explanation of the constitution of the salts which are commonly assumed to be produced by certain imaginary compounds, called polybasic and conjugated acids.

- Proof that the results of electrolytic experiments justify the adoption of radicals.
- A demonstration of the impolicy of attempting to separate Organic from Inorganic Chemistry.
- A systematic nomenclature, applicable to every description of chemical compound.

I adduce evidence to prove that the following Hypotheses (among many others) propagate Fallacies for Truths, and thereby obstruct the progress of the science:—

- That water contains only one atom of each of its two elements.
- That elementary atoms combine in multiple proportions.
- That salts contain acids and bases.
- That such things exist as sesquioxides, polyatomic alcohols, and conjugated and polybasic acids.
- That all salts are formed on the model of water.
- That all compounds which contain azote are formed on the model of ammonia.
- That isolated elements do not exist, so that free chlorine and free hydrogen are binary compounds.

Every experiment quoted in this work is derived from the writings of the chemists, whose theories I oppose. The arguments rest therefore upon facts which will not be impugned.

I treat all unsettled and disputed doctrines as if the reader intended to form an independent and impartial opinion upon them. I pay no respect to any other Authority than that of Facts and the Probabilities which arise from concurrent circumstantial evidence.

The adoption of the Radical Theory would put an end to much false philosophy, would speedily extend our knowledge of organic compounds, and facilitate the study and improvement of every department of the science.

Longton Lodge, Sydenham,
24*th December*, 1857.

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A MEMOIR, containing a succinct account of the principles of the Radical Theory, accompanied by historical notes, in disproof of M. Gerhardt's claim to the invention of the theory of hydration of acids and bases, was presented to the Chemical Society in the month of June, 1855.

The printing of this Volume was commenced in the Spring of 1856. The Author's illness occasioned an interruption of nearly a year. The work was afterwards slowly proceeded with until the end of the year 1857.

In consequence of this interruption, and of the progress of the science during the years 1856 and 1857, it happens that the earlier sections of the work are not always in strict accordance with the later sections. Thus, the theory of the Anhydrides and that of the Conjugated Sulpho-acids, as first described, undergo important modifications in the article which commences at page 480. In such cases, the Author's opinions are to be taken as they are expressed in the latest statements.

The Radical Theory in Chemistry.

On the Proximate Constitution of Acids, Bases, and Salts.

TWENTY-THREE years ago I read, before the Philosophical Society of Glasgow, a paper on "The Proximate Constitution of Chemical Compounds," and in the year 1834, I published that Paper, as part of a work entitled "*Chemical Recreations.*"

The chemical doctrines which I then advocated differed considerably from the doctrines that were entertained by most chemists of that period, and they met with the hostility which constituted authorities commonly oppose to radical theories and organic changes. The book was well received by the public, and the edition of 3,000 copies was exhausted in two years; but as the chief purpose of the work was to teach experimental chemistry, when it was reprinted, the theoretical chapter was omitted, and, though I never abandoned my radical theories, I have, from that time to the present, ceased to press them upon the attention of chemists. Even now, after a silence of nearly a quarter of a century, I return to the subject only because I am provoked to it by a challenge from Mr. Charles Gerhardt. I hope, for these reasons, that I shall not be considered importunate, especially as the subject to be discussed is one upon which the minds of philosophers are wholly unsettled, and upon which it is desirable that some intelligible and comprehensive theory should replace the multiform and misty hypotheses by which the chemical world is now governed.

Mr. Gerhardt's challenge is contained in a paper that was published in *Liebig's Annalen der Chemie*, for August, 1854, and it runs thus:—

"Mr. Kolbe glows with indignation over what he calls 'Williamson's Theory of Water, Ethers, and Acids.' I do not comprehend, how a theory, whose first and weightiest points were demonstrated by me several years ago, is suddenly become 'Williamson's' theory. Now,

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who was it that first said, that water was H^2O, and not HO; that hydrate of potash was KHO and not KO,HO; that oxide of potassium was K^2O and not KO; that ether was Ae^2O and not AeO; that the so-called aqueous nitric acid was NHO^3 and not NO^5,HO, and so forth? Who was it that devised the method of writing which is employed by Williamson and the other English chemists to exhibit the differences of these methods of combination?

"The main point which now divides chemists into two parties, lies *in the relative atomic weights* between oxides and their hydrates, ether and alcohol, the so-called anhydrous and their corresponding hydrated monobasic acids. According to the old school, all hydrated oxides—alcohol as well as the hydrated monobasic acids—contain the elements of water. This now did I, before all other chemists, deny. Caustic potash, alcohol, acetic acid, I said, contained no water: Berzelius and the old school doubled the atomic weights of these bodies, and declared that they contained water. This is the fundamental difference between the two theories.

"For a long time, I and Laurent were the only advocates of my opinions. Afterwards Chancel adopted them, and at a later period Williamson."

Such are Mr. Gerhardt's claims.

I undertake to reply to them, because I can prove that he has no title to the theories which he so boldly claims.

As the question must be treated historically, I begin by inquiring, when it was that Mr. Gerhardt himself first published these theories? He tells us,[1] that it was in the year 1842. I ask, then, did any one else publish the same theories before that year? That is the question to which I am about to reply.

In the year 1826, Dr. Thomas Clark published in Glasgow, for the use of his students in the Mechanics' Institution, a series of Tables of Chemical Formulæ, a copy of which I now reprint. The formulæ given in these Tables for water is HO,H; that for anhydrous potash is PO,P; that for alcohol is HO; CH,H; CH,H,H. Ether and hydrate of potash do not appear in Dr. Clark's Tables; but the formulæ of the hydrated acids, namely of aquafortis, oil of vitriol, oxalic acid, acetic acid, &c., show that all these contain as base *a single atom of hydrogen*, and are *without water*.

Examples:—

Aquafortis . . .	AO,O,O; H
Oil of vitriol . .	SO,O; H
Oxalic acid . . .	CO,O; H
Acetic acid . . .	CH,H,H; CO,O; H

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[1] *Comptes Rendus des Travaux de Chimie*, 1850, p. 428.

TABLES

ILLUSTRATIVE OF

MR. CLARK'S CHEMICAL LECTURES,

DELIVERED TO THE

GLASGOW MECHANICS' INSTITUTION,

SESSIONS 1826–7, & 1827–8.

Atomic Weights, or Primitive Combining Proportions of Simple Substances.

	SIGN.	
Aluminum	Al	7
[Ammoniacum (A H, H, H, H)	Am	9]
Antimony	An	22
Arsenic	As	38
Azote	A	7
Barium	Ba	35
Bismuth	Bs	36
Boron	B	11
Bromine	Br	38
Cadmium	Cd	28
Calcium	Ca	10
Carbon	C	6
Cerium	Ce	23
Chlorine	Ch	18
Chrome	Chr	14
Cobalt	Cb	15
Columbium	Cl	92
Copper	Cp	16
Fluorine	F	9
Glucinum	Gc	13
Gold	G	33
Hydrogen	H	½
Iodine	I	62
Iridium	Id	
Iron	Ir	14
Lead	Ld	52
Lithium	Li	5
Magnesium	Mg	6
Manganese	Mn	14
Mercury	Mr	50
Molybden	Mo	24
Nickel	Ni	15
Osmium	Os	
Oxygen	O	8
Palladium	Pd	28
Phosphorus	Ph	16
Platinum	Pt	24
Potassium	P	20
Rhodium	R	?
Selenium	Se	20
Silicon	Si	8
Silver	Sv	55
Sodium	So	12
Strontium	Sr	22
Sulphur	S	8
Tellurium	Te	32
Tin	Tn	29
Titanium	Tt	16
Tungsten	Tg	48
Uranium	U	72
Yttrium	Y	16
Zinc	Zn	16
Zirconium	Zr	17

Gases and Vapours of which one volume corresponds with one atom.

	SIGN.	
Oxygen	O	8
Azote	A	7
Hydrogen	H	½
Chlorine	Ch	18
Iodine	I	62
Mercury	Mr	50
Prussine, or Cyanogen	CA	13
Sulphurous acid	SO	16
Sulphuretted hydrogen	SH	8½

	SIGN.	
Seleniuretted hydrogen	Se H	20½
Nitrous acid	A O, O	23
Perchloride of tin	Ch Tn, Ch	65
Perchloride of titanium	Ch Tt, Ch	52
Chloride of silicium	Ch Si, Ch	44
Fluoride of silicium	F Si, F	26

Gases and Vapours of which two volumes correspond with one atom.

Water	H O, H	9
Nitric oxide	A O	15
Nitrous oxide	A O. A	22
Carbonic oxide	C O	14
Carbonic acid	C O, O	22
Deutoxide of chlorine	Ch O, O	34
Gas of marshes	C H, H, H, H	8
Olefiant gas	C H, H, H, H ; C	14
Alcohol	H O ; C H, H ; C, H, H, H	23
Sulphuret of carbon	C S, S, S, S	38
Muriatic acid	Ch, H	18½
Hydriodine acid	I H	62½
Hydroprussine acid	C A, H	13½
Ammonia	A H, H, H	8½
Phosphuretted hydrogen	Ph H, H, H ? (Dumas)	17½
Arseniuretted hydrogen	As H, H, H (Do.)	39
Protochloride of phosphorus	Ch, Ph, Ch, Ch	70
Protochloride of arsenic	Ch As, Ch, Ch	93
Chloride of boron	Ch B, Ch, Ch	65
Fluoride of boron	F B, F, F	28
Chloride of cyanogen	Ch, C A	31
Chloride of carbonic oxide	Ch, C O ; Ch	50
Chloride of olefiant gas	Ch (C H, H, H, H ; C ;) Ch	5

Gases and Vapours of which four volumes correspond with one atom.

Phosphuretted hydrogen, (spontaneously inflammable)	Ph H ; Ph H, H ; Ph H, H, H ? (Dumas)	51

Oxides of Lead.

Brown	Ld O	60
Yellow	Ld O, Ld	112
Intermediate ?	Ld O, Ld ; Ld O	172
Red	Ld O, Ld ; Ld O ; Ld O	232

Peroxide of tin	Tn O	7
Protoxide of tin	Tn O, Tn	66
Titanic acid	Tt O	24
Silica	Si O	16
Sulphurous acid	S O	16
Carbonic acid	C O, O	22
Nitrous acid	A O, O	23
Hydrosulphur acid	S H	8½
Muriatic acid	Ch H	18½
Hydriodine acid	I H	62½
Hydroprussine acid	C A, H	13½
Oil of vitriol	S O, O ; H	24½
Aqua fortis	A O,O, O ; H	31½
Chromic acid	Chr O, O ; H	30½

	SIGN.	
Oxalic acid	CO,O; H	22
Formic acid	H,CO,O; H	23
Succinic acid	CH,H; CO,O; H	29½
Acetic acid	CH,H,H; CO,O; H	30
Tartaric acid	CH,H; CO,O,O; H ?	37
Sulphuret of sodium	SSo	20
Sulphuret of potassium	SP	28
Sulphuret of ammoniacum	SAm	17
Sulphuret of barium	SBa	43
(The above sulphurets are soluble: the following are insoluble.)		
Sulphuret of antimony	SAn	30
Sulphuret of copper	SCp	24
Sulphuret of copper, with copper	SCp,Cp	40
Sulphuret of iron	SIr	22
Bisulphuret of lead (pyrites)	SIr,S	30
Sulphuret of lead (galena)	SLd	60
Sulphuret of lead, with lead	SLd,Ld	112
Cinnabar	SMr	58
Ethiop's mineral	SMr,Mr	108
Sulphuret of tin	STn	37
Mosaic gold	STn,S	45
Zinc blende	SZn	24
Copper pyrites	SCp,SIr	46
Chloride of sodium	ChSo	30
Chloride of potassium	ChP	38
Sal ammoniac	ChAm	27
Chloride of barium	ChBa+ W=53+9	= 62
Chloride of copper	ChCp+1½ W=34+13½	= 47½
Chloride of copper, with copper	ChCp,Cp	50
Chloride of gold	ChG	51
Protochloride of iron	ChIr	32
Perchloride of iron	ChIr; ChIr,Ch	82
Chloride of lead	ChLd	70
Corrosive sublimate	ChMr	68
Calomel	ChMr,Mr	118
Protochloride of tin	ChTn+2 W=47+18	= 65
Perchloride of tin	ChTn,Ch	65
Chloride of zinc	ChZn	34
Sulphate of soda	SO,O; So+5 W=36+45	= 81
Sulphate of potash	SO,O;P	44
Sulphate of ammonia	SO,O;Am	33
Sulphate of lead	SO,O;Ld	76
Sulphate of barytes	SO,O;Ba	59
Sulphate of lime (alabaster)	SO,O;Ca + W=34+9	= 43
Sulphate of copper	SO,O;Cp +2½ W=40+22½	= 62½
Sulphate of manganese	SO,O;Mn+2½ W=38+22½	= 60½
Sulphate of iron	SO,O;Ir +3 W=38+27	= 65
Sulphate of zinc	SO,O;Zn +3½ W=40+31½	= 71½
Sulphate of magnesia	SO,O;Mg+3½ W=30+31½	= 61½
Sulphate of mercury	SO,O;Mr	74
Do. with mercury	SO,O;Mr;Mr	124
Bisulphate of tin	SO,O;Tn: SO,O	77
Persulphate of iron	SO,O;Ir: SO,O;Ir; SO,O	100
Persulphate of manganese	SO,O;Mn: SO,O;Mn; SO,O	100
Sulphate of chrome	SO,O;Chr: SO,O;Chr; SO,O	100
Sulphate of alumina	SO,O;Al: SO,O;Al; SO,O	86

	SIGN.	
Potash alum	SO,O;P+SO,O;Al;SO,O;Al; SO,O + 12 W = 44 + 86 + 108	= 238
Nitrate of lead	AO,O O; Ld	83
Nitrate of barytes	AO,O,O; Ba	66
Nitrate of strontites	AO,O,O; Sr + 2 W = 53 + 18	= 71
Nitrate of iron	AO,O,O; Ir + 3½ W = 45 + 31½	= 76½
Nitrate of copper	AO,O,O; Cp + 3½ W = 47 + 31½	= 78½
Nitrate of potash	AO,O,O; P	51
Nitrate of ammonia	AO,O,O; Am	40
Nitrate of soda	AO,O,O; So	43
Nitrate of silver	AO,O,O; Sv	86
Yellow chromate of potash	ChrO,O; P	50
Yellow chromate of lead	ChrO,O; Ld	82
Oxalate of ammonia	CO,O; Am	31
Oxalate of lime	CO,O; Ca	32
Acetate of lead	CH,H,H;CO,O; Ld + 1½ W = 81½ + 13½	= 95
Acetate of soda	CH,H,H;CO,O; So + 3 W = 41½ + 27	= 68½
Acetate of lime	CH,H,H;CO,O; Ca + 3 W = 39½ + 27	= 66½
Acetate of copper	CH,H,H;CO,O; Cp + ½ W = 45½ + 4½	= 50
Tartrate of potash	CH,H;CO,O,O; P	57

Examples of Acid Salts.

Hydrosulphurate of potassium	SH, SP	36½
Supersulphate of potash	SO,O;H: SO,O;P	86½
Red chromate of potash	ChrO,O; H: ChrO,O;P?	80½
Cream of tartar	CH,H;CO,O,O; H: CH,H;CO,O,O; P	94½

Examples of Sub-salts.

Goulard's extract	CH,H,H;CO,O;Ld: LdO,Ld	193½
Red chromate of lead	ChrO,O;Ld: LdO,Ld: ChrO,O;Ld	276

Examples of Double Salts.

Sulphate of potash and magnesia	SO,O;P: SO,O;Mg + 3 W = 74 + 27	= 110
Sulphate of potash and zinc	SO,O;P: SO,O;Zn + 3 W = 84 + 27	= 111
Ferroprusside of potassium	CA,Ir;CA,P: CA,P + 1½ W = 93 + 13½	= 106½
Carbonate of lead	CO,O; Ld O,Ld	134
Carbonate of barytes	CO,O; Ba O,Ba	100
Carbonate of strontites	CO,O; Sr O,Sr	74
Carbonate of lime	CO,O; Ca O,Ca	50
Carbonate of magnesia	CO,O; MgO,Mg	42
Carbonate of iron	CO,O; Ir O,Ir	58
Carbonate of manganese	CO,O; MnO,Mn	58
Carbonate of zinc	CO,O; Zn O,Zn	52
Carbonate of soda	CO,O; So O,So + 10 W = 45 + 90	= 144
Do.	CO,O; So O,So + 7 W = 54 + 63	= 117
Do.	CO,O; So O,So + W = 54 + 9	= 63
Carbonate of potash	CO,O; P O,P + 2 W = 70 + 18	= 88
Carbonate of ammonia	CO,O; AmO; Am	= 48
Supercarbonate of potash	CO,O; HO,H: CO,O;PO,P	= 101

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The theories indicated by these formulæ were fully developed in Dr. Clark's lectures. I heard some of those lectures delivered; I had at the period referred to, frequent discussions with Dr. Clark on these subjects; it is easy to prove the genuineness of the printed tables, because the printer's name is attached; and the proof is therefore conclusive, that some of the fundamental theories, which Mr. Gerhardt claims to have first published in 1842, were publicly taught by Dr. Clark to the mechanics of Glasgow sixteen years previously.

All these theories were minutely described in my publication of 1834, with many additions that had occurred to me during several years' consideration of the subject. That book attracted the special notice of another French chemist—M. Dumas, who, in a course of lectures delivered in Paris in 1837,[1] treated it with frequent and unsparing ridicule. Five years afterwards, Mr. Gerhardt *discovered* the theories of which my book, thus publicly condemned in Paris, contained the full development.

I shall quote two or three passages from that book to show the wonderful coincidence between Mr. Gerhardt's theories of 1842 and mine of 1834.

First example, respecting the Hydrate of Potash. This compound is not contained in Dr. Clark's Tables. Mr. Gerhardt's formula for it is KHO, and he states it to be one of the strong points of his theory, that *the hydrated protoxides contain no water*. Upon that fundamental idea is founded the modern method of representing the composition of salts in reference to the composition of water, taken as a model. The three formulæ—

$$\begin{matrix}H\\H\end{matrix}O \qquad \begin{matrix}K\\K\end{matrix}O \qquad \begin{matrix}K\\H\end{matrix}O$$

contain the essence of this system. Mr. Gerhardt declares that he originated that theory in 1842; but here is my account of it, published eight years previously:—

I quote from *Chemical Recreations*:—

"The hydrate of a metallic protoxide contains one atom of oxygen, one atom of hydrogen, and one atom of metal.

"Every chemist but myself assumes the hydrates of metallic protoxides to consist of metallic protoxides combined with water. They make this assumption even in cases where the hydrates have been exposed, under common atmospheric pressure, to a *red heat*, without suffering decomposition or giving off a particle of steam. . . . But my opinion is, that the hydrates of the metallic protoxides contain neither protoxides nor water, but are constituted of one atom each of metal, oxygen, and hydrogen. This is the *ultimate* constitution—what the *proximate* constitution is, I cannot tell. It may be $KH+O$, or $KO+H$, or K+HO; we have no means of determining *which*. I rest upon the ultimate constitution."[1]

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[1] *Leçons sur la Philosophie Chimique*, 8vo. Paris, 1837.

What I meant by the difference between the PROXIMATE and ULTIMATE constitution of a compound, is explained in the following quotation:—[2]

"I have denounced the doctrine of *proximate constitution* as the ever-flowing source of chemical blunders, whilst in treating of the limits of combination, and in the discrimination of positive and negative substances, I have admitted the doctrine in its substantial features. Permit me to reconcile these apparent contradictions.

"According to my theoretical notions, every compound is formed of a *positive* substance and a *negative* substance, each of which *may be* either an element or a compound. Thus the compound AB contains the positive element A and the negative element B. The compound AAB contains the positive element A and the comparatively negative compound AB. The compound ABB contains the comparatively positive compound AB and the negative element B. Yet this is all matter of theory and opinion, for I am unable to prove that the compound AAB is not formed by the direct combination of AA with B, and the compound ABB by the direct combination of A with BB. The latter is the prevailing theory—the theory of DALTON; and though I disbelieve it, and consider it utterly inconsistent with the facts of chemistry, it may be true. But even admitting its truth, the light it throws on chemical composition is a feeble one; for what does it discover when brought to bear upon the compound ABC? Does this compound arise from the simultaneous combination of the three elements, or does AB combine with C, or AC with B, or A with BC? And in the case of the compound ABCC—is this constituted of A+BCC, or AB+CC, or ABC+C, or AC+BC, or AAC+BBCCC?—These are cases of perplexity, in the disentanglement of which the atomic theory is of no service. It boots not that we know how many elementary atoms of A,B, and C are contained in a given compound. These are but the *ultimate* constituents; and what we want to know is, how these are combined together into *proximate* constituents.

"This is a problem for future times to solve, and it is a problem of that importance that we are not warranted in *assuming* its solution, merely for the purpose of grounding a nomenclature and a system of arrangement upon the assumed solution. Yet this is done in the antiphlogistic nomenclature and theory. *It is assumed that sulphate of barytes contains barytes and sulphuric acid, that nitrate of potash contains potash and nitric acid, that caustic soda contains protoxide of sodium and water;*—and these assumptions form the groundwork of the French theory and nomenclature—the groundwork of the theory adopted by [illegible] gifted Berzelius, who has spent twenty years in vain attempts to establish it. The root of the system of this chemist is, that in the sulphate of lead the oxygen is so divided between the sulphur and the lead, that the portion combined with the former bears to the portion combined with the latter the ratio of 3 to 1. I hesitate not to say that *this is an assumption incapable of proof.*

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[1] GRIFFIN, J. J., *Chemical Recreations*, 7th edit. 1834, page 229.

[2] *Ibid.* page 242.

"Let us examine the formation of sulphate of lead with a view to discover its proximate constituents:—[1]

a. When 4 parts of sulphur are converted into sulphuric acid by digestion with nitric acid, and the solution is precipitated by a solution of lead, the resulting sulphate of lead weighs 38, containing 26 of lead, and consequently 8 of oxygen.

b. When 26 parts of lead are dissolved in nitric acid, and the solution is precipitated by sulphuric acid, or by the solution of a sulphate, the resulting sulphate of lead weighs 38, containing 4 of sulphur, and 8 of oxygen.

c. When 30 parts of sulphuret of lead, containing lead 26 and sulphur 4, are converted by oxidation into sulphate of lead, the weight of the product is 38, including 8 of oxygen.

d. When 35 parts of chloride of lead, which contain chlorine 9 and lead 26, are precipitated by sulphuric acid, the resulting sulphate of lead weighs 38, and contains 4 of sulphur and 8 of oxygen.

e. When 30 parts of brown oxide of lead, which contains lead 26, oxygen 4, are exposed to an atmosphere of sulphurous acid gas, they absorb 8 parts of that acid, equal to oxygen 4 and sulphur 4, and produce 38 parts of sulphate of lead.

"The information afforded by the above experiments is, that sulphate of lead is composed of—

Lead	26
Sulphur	4
Oxygen	8
	38

But none of these experiments afford the least insight into the manner in which these elements are combined together. The assumption that one-fourth of the oxygen is combined with the lead and three-fourths with the sulphur, is perfectly gratuitous.

"The most direct of the whole five experiments, *e*, is in favour of the or Fusion that sulphate of lead is PbO + SO, a conclusion very different from that which BERZELIUS comes to, but which agrees precisely with my opinion that 26 parts of lead is the quantity which is equivalent in combination to a volume of hydrogen.

---

[1] In one of Mr. Gerhardt's publications (his "Introduction to the Study of Unitary Chemistry") he follows precisely this line of argument, with the single difference of using sulphate of barytes, instead of sulphate of lead, as his illustration.

"It is very well to admit the doctrine of proximate constitution in theory, because it is useful in explaining a variety of phenomena, such as chemical combinations, electrical decompositions, and the like. But when we come to arrange the products of chemistry into a system, and to give them systematic names, the only safe way to view them is in relation to their ultimate constitution. It is only by founding a nomenclature upon this basis, that we can hope to avoid the perplexities which arise from the *guess-work* of the proximatists.

"But, it may be said, in rejecting proximate constitution, and stating only the ultimate constitution of compounds, you give false notions of secondary compounds, the properties of which depend upon the nature of their proximate constituents. Thus, sulphate of barytes derives its properties from the sulphuric acid and barytes which compose it.

"I reply, No!—Sulphate of barytes derives its properties from the barium, sulphur, and oxygen which compose it, just as sulphuric acid and barytes, considered as distinct compounds, derive *their* properties from the same ultimate elements. In short, viewed in any light, it is the ultimate elements which determine the character of the compounds. There is a fashion, but no utility, in assuming proximate constitution, as the basis of a systematic nomenclature."

Second Example. Mr. Gerhardt states that he was the first to deny, that the hydrated acids contained the elements of water. In that, however, he is mistaken. Dr. Clark's Tables prove him to have taught that doctrine sixteen years previously, and I will now quote from my Paper of 1834 a full development of the theory which considers hydrated acids as salts of hydrogen.

[In making this quotation I have changed figures that represent *weights* of ultimate elements for symbols that represent *atoms*—the change being made according to the atomic weights given in another part of the same book.]

"The following Table exhibits the constitution of a variety of compounds in which hydrogen is an essential constituent. I have inserted a few compounds which contain no hydrogen, for the purpose of contrasting their constitution with that of particular hydrogen compounds somewhat related to them :—

H	O	–	Peroxide of Hydrogen.
H^2	O	–	Water.
H	–	S	Sulphuretted Hydrogen Gas.
H	–	Cl	Muriatic Acid Gas.
H	O^3	Cl	Hydrate of Chloric Acid.
H	O^3	N	— — Nitric Acid.
	O^5	N^2	Dry Nitric Acid (chimerical).
	O^3	N,K	Nitrate of Potash.
H	O^2	N	Hydrate of Hyponitrous Acid.
H	O^2	S	— — Sulphuric Acid.
	O^2	S,K	Sulphate of Potash.
H	O^2	C	Effloresced Oxalic Acid.
H	–	C	Bicarburet of Hydrogen.
H^2	–	C	Olefiant Gas.
H^4	–	C	Gas of Marshes.
H	–	C,N	Prussic Acid.
H^3	–	N	Ammonia Gas.
H^4	–	N	Ammonium (imaginary).
H^4	–	N, Cl	Sal Ammoniac (Chloride of Ammonium.)
H^4	O^3	N^2	Nitrate of Ammonia.
H	O	K	Caustic Potash.
H	O	Ca	Hydrate of Lime (Slaked Lime).
	O	Ca^2	Anhydrous Lime (Quick Lime).
H	O	Si	Hydrate of Silica.
	O	Si^2	Silica.

" I beg to call the student's particular attention to this Table, and to the following two memoranda :—

" I. The difference between an ACID (namely, a *hydrated* acid, and a SALT, is this :—The former contains one combining proportion of *hydrogen*, where the latter, instead of this hydrogen, contains exactly one combining proportion of a *metal*, *all other constituents*, both of the acid and salt, remaining the same :—

Examples :—

S, O^2, H = Sulphuric Acid.
S, O^2, K = Sulphate of Potash.

N, O^3, H = Nitric Acid.
N, O^3, K = Nitrate of Potash.

C, O^2, H = Oxalic Acid
C, O^2, K = Oxalate of Potash.

$Cl, \quad , H$ = Muriatic Acid.
$Cl, \quad , K$ = Muriate of Potash.

Cl,O^3, H = Chloric Acid.
Cl,O^3, K = Chlorate of Potash.

Numberless illustrations of this sort could be given, but these suffice to confirm the above proposition, viz., that the hydrated acids are simply salts of hydrogen. The reason why I wish to direct the student's attention to this subject is, that in every chemical book which falls into his hand, he will find the absurd proposition gravely inculcated, that the *salts* CONTAIN *acids;* that, for example—

Sulphate of potash *contains* sulphuric acid,
Nitrate of potash *contains* nitric acid,
Oxalate of potash *contains* oxalic acid,
Muriate of potash *contains* muriatic acid,
Chlorate of potash *contains* chloric acid;

all of which assertions are destitute of the smallest foundation in truth, and are, indeed, self-evident impossibilities. In fact, it would be quite as correct to say, that sulphuric acid contains sulphate of potash, as to say that sulphate of potash contains sulphuric acid. The truth is, that they are two distinct compounds, each of which contains the same number of constituent atoms, but neither of which does, or can, form *part* of the other.

" II. *Secondly*, the difference between a *hydrate of a protoxide of a metal* (such as slaked lime) and an *anhydrous protoxide of a metal* (such as quicklime) is this:—The former contains a combining proportion of hydrogen where the latter contains a combining proportion of a metal. The difference between a hydrated protoxide and an anhydrous protoxide is, therefore, the same as the difference between an acid and a salt. In both cases, one of the compounds contains a combining proportion of hydrogen, which is replaced in the other by a combining proportion of a metal.

EXAMPLE:—

Ca,H,O	Hydrate of lime.
Ca,Ca,O	Anhydrous lime.

" This is the case with all the metallic protoxides. It is needless to incumber the reasoning with illustrations.

" These hydrates of protoxides contain no water, for they contain but one proportion of hydrogen, whereas water contains two proportions. Yet they give off water when exposed to heat, and they produce nothing else than anhydrous protoxides. There is no difficulty in ascertaining how this effect is produced, or in showing the source of the constituents from which the water is *produced* by this experiment:—

Two proportions of Hydrate of Lime.	What they produce by exposure to heat.
$CaHO$	$CaCaO$
$CaHO$	$H\,H\,O$

"The greater part of the numerous acids and salts which contain oxygen as a constituent, appear to fall within the limits of the following scheme, in which M signifies the *metal* or *hydrogen* (*i. e.* the electro-positive constituent), R the *radical* of the salt, and O the oxygen; the figures denoting the number of atoms present of the element after which they stand:—

CLASS I.	$M^1R^1O^1$.	Silicates. Many of the salts in which both M and R are metals. Hyposulphites.
,, II.	$M^1R^1O^2$.	Sulphates. Oxalates. Chlorites. Hyponitrites (Nitrites). Manganesates. Seleniates.
,, III.	$M^1R^1O^3$.	Nitrates. Chlorates. Iodates. Bromates.
,, IV.	$M^1R^1O^4$.	Perchlorates.
,, V.	$M^2R^1O^3$.	These are a species of basic salts of Class 2, namely,—$MO + RO + MO$. Carbonates.
,, VI.	$M^1R^2O^3$.	These are a species of acid salts of Class 2, namely, $MO + RO + RO$. Many metallic salts. Hyposulphates.
,, VII.	$M^2R^2O^3$.	Sulphites. Selenites.

"The SUPER- or BI-*salts* commonly contain an atom of a metallic salt and an atom of a hydrogen salt. Thus, bisulphate of potash contains an atom of sulphate of potash, and an atom of oil of vitriol; binoxalate of soda contains an atom of oxalic acid, and an atom of oxalate of soda.

"I think that the word ACID, taken as a substantive name, ought to be disused in chemistry. It has done mischief. It ought to be employed only as denoting a quality."[1]

Such is the theory of acids and salts, as advocated by me in 1834. With what justice can M. Gerhardt proclaim, that the first and weightiest points of this theory were originally demonstrated by him in 1842?

I have yet another claim to examine. "Who was it," asks M. Gerhardt, "that devised the *method of writing*, which is employed by Williamson and the other English chemists to exhibit the differences of these methods of combination?"

Now there are *two* "methods of writing" to be noticed in M. Gerhardt's publications. The first consists in writing the formulæ of chemical compounds in a ternary form, as if the symbols were placed at the three angles of a triangle, $\begin{matrix}\mathrm{K}\\\mathrm{K}\end{matrix}\mathrm{O}$.

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[1] GRIFFIN, J. J., *Chemical Recreations*, 7th edit., 1834, pp. 92-6.

The other *method of writing* consists in constructing formulæ in the manner which Gerhardt and Laurent term UNITARY *formulæ*. These formulæ are framed in accordance with the following hypotheses:—namely, that salts do not consist of acids and bases; that we know nothing of the proximate constitution of salts; that it is impossible to determine in what manner the atoms of the ultimate elements of salts are grouped together; that, consequently, the construction of dualistic formulæ, which affect to explain the constitution of salts, is unwarranted; and, finally, that the symbols composing each formula should be made to represent only a single molecule.

Here then we have two decidedly different *methods of writing*. We have the *unitary* system, founded upon the know-nothing principle, and we have the *ternary* system, founded upon that perfect knowledge of proximate constitution, which enables the chemist unerringly to divide the components of every salt into three distinct portions, upon the model of water.

I am not quite certain which of these two "methods of writing" it is that M. Gerhardt claims to have invented; but, if I may judge from the formulæ commonly employed by Professor Williamson, I must conclude that it is the triangular system to which he refers. The invention of that kind of formula may, for aught I know, be due to M. Gerhardt. It certainly does not belong to me; and, for reasons that I shall hereafter state, I disapprove of it.

But the ternary formulæ are only of recent invention. The formulæ that M. Gerhardt used for years previously, and which he strongly recommended in his Journal, are the *unitary formulæ*, in the construction of which he recommends especial care to be taken, to give no indication of the proximate constitution of the compounds which the formulæ are meant to represent.

In expressing an opinion adverse to such *unitary* formulæ, I no doubt agree with the general body of chemists; but treating the question, as I do now, historically, truth obliges me to admit, that, for their introduction to chemists, it is not M. Gerhardt, but I that am responsible. The evidence of this fact is contained in the extract from my *Romance of Chemistry*, which I have quoted at page 10. In that article I discussed the question of proximate and ultimate constitution, and after showing that the theory which assumes that salts consist of acids and bases, is one that does not admit of proof, I recommended that the formulæ of compounds should in all cases be made to represent only their ultimate elements. I added, indeed, that such formulæ should be written in a systematic manner (and not designedly hap-hazard as Mr. Laurent advises), but still I recommended the formulæ to be so written as to express no theory of the proximate constitution of the compounds; and in order to show that the system thus recommended was quite practical, I presented in *Chemical Recreations* a series of tables of unitary formulæ, representing nearly 800 of the then best known compounds of *inorganic chemistry*, to which department of chemistry alone, did I apply the unitary system. That was in the year 1834. Reconsidering the matter in 1856, and including in the reconsideration what is now known of the nature and constitution of the hydrocarbons and other compound radicals, I am of opinion that unitary formulæ are equally inapplicable to organic and to inorganic compounds. We now possess, thanks to the discoveries made in organic chemistry, many of them due to Gerhardt, much positive knowledge of the proximate constitution of chemical compounds, and this knowledge the use of unitary formulæ would hide or mystify. A mere glance at Gmelin's account of Isomerism, Polymerism, and Metamerism,[1] affords conclusive evidence of the worthlessness of unitary formulæ in organic chemistry, since the cases are numerous in which a single unitary formula would indicate two, three, or four different organic compounds. Thus, the formula $C^6H^{12}O^2$ would represent—

Butyrate of ethyl . . .	$C^2H^5,C^4H^7O^2$.
Formiate of amyl . . .	C^5H^{11},CHO^2.
Valerate of methyl . .	$CH^3,C^5H^9O^2$.
Hydrated caproic acid .	$H,C^6H^{11}O^2$.

In this case, eight well-known radicals possessed of highly-characteristic properties would be smothered by the unitary formula, $C^6H^{12}O^2$. Whole pages of similar difficulties could be quoted; but it is needless to quote them, when a single example extinguishes all faith in the precision and perspicuity of that "method of writing," which is called *unitary*.

These particulars constitute my reply to Mr. Gerhardt's challenge.

He asked, who first published the unitary theory of hydration? I reply, that the unitary theory of hydrated *Acids* was first published by Dr. Clark, and that of hydrated *Bases* by me. Mr. Gerhardt took up these theories when they were neglected or decried by other chemists, and, in conjunction with Laurent, applied them to organic chemistry, and used them as a guide to numerous and brilliant discoveries. That is a real merit, which I esteem. He did chemists another important service, which many have ridiculed and few have properly appreciated. He showed how they could get rid of those troublesome hypothetical compounds, the *sesquioxides*. For that service chemists will yet thank him. But his challenge to the world, to disprove his claim to the invention of the theories of hydration that I have cited in these pages is unjust to Dr. Clark and to me.

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[1] Gmelin's Handbook of Chemistry, vii. 66.

The Binary Theory of Salts.

I have already mentioned that my attack on Lavoisier's theory of the salts was treated by M. Dumas with ridicule; but, notwithstanding his expressed contempt, my speculations appear to have roused him to consider how far they might endanger the continued acceptability of Lavoisier's theory. He describes himself to have been actuated by the arguments of Davy and Dulong; but these chemists had published their theories twenty years before, and I might ask, how it happened that they remained without reply from 1816 to 1837? Was it not that my paper first brought the subject distinctly into public notice? That I may not be charged with undue presumption in claiming the credit of having first drawn attention to this subject, I will point out the fact, that none of the following systematic works contain any allusion to the binary theory of the salts as propounded by Davy and Dulong, or express any doubt of the absolute perfection of the theory of Lavoisier.

Dumas, Traité de Chimie appliquée aux arts. Liége, 1848. Reprinted from the Paris edition of about 1830.
Thenard, Traité de Chimie Elémentaire. Paris, 1827.
Gay-Lussac, Cours de Chimie, professé à la Faculté des Sciences, comprenant l'histoire des sels, la Chimie végétale et animale. Paris, 1833. The lectures were delivered in 1828.
Berzelius, Lehrbuch der Chemie, übersetzt von F. Wöhler. Dresden, 1831.
Gmelin, Handbuch der theoretischen Chemie. Frankfort, 1827.
Schubarth, Elemente der technischen Chemie. Berlin, 1835.
Brande, Manual of Chemistry. London, 1830.
Henry, Elements of Experimental Chemistry. London, 1829.
Thomson, System of Chemistry of Inorganic Bodies. London, 1831.

If the Binary Theory of Salts was clearly explained, and Lavoisier's theory as clearly refuted by Davy and Dulong in 1815 and 1816, how came all these eminent compilers of systems to take no notice of circumstances so remarkable?

M. Dumas discussed the question as follows:—

"I do not," he says,[1] "undertake to demonstrate that the system of Lavoisier on the constitution of the salts is exact. It was established on a principle of convenience. It is not based upon peremptory proofs; but I willingly undertake to show that, before all other systems that have been proposed, there rise objections of still greater force than those which rest against the theory of Lavoisier.

"Let us commence with the system of Davy, to the support of which Dulong has lent his powerful aid. According to Lavoisier there are only oxygen acids. Davy said, I will show you that all acids are hydrogen acids. You believe, said he, that the compound denoted by SO^3 is an acid. In that belief you are entirely mistaken. SO^3 is not an acid. I defy you to show me the characters of an acid in that compound. And strange to say, if we accepted Davy's challenge, we should be powerless; for it is really impossible to prove that anhydrous sulphuric acid is an acid.

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[1] Dumas, Leçons sur la Philosophie Chimique. 8vo. Paris, 1837, p. 337.

"The true acid, said Davy, is the ordinary liquid acid, SO^3, H^2O. But he wrote it in another manner, thus, SO^4+H^2. You will readily conceive that this acid in contact with the bases ought to behave like other hydracids. Its hydrogen would form water with the oxygen of the base, and its radical SO^4 would combine with the metal; so that the substance that we call sulphate of lead, would not be constituted like SO^3+PbO, but like SO^4+Pb.

"Dulong supported the ideas of Davy by considerations on the oxalates which, on Davy's system, would result from the combination of carbonic acid with the metals; a view which gives a ready explanation of the properties of the oxalates.

"It is difficult to attack this theory of Davy's. It appears to be so well founded. It is so rational. It so greatly simplifies chemistry. It leaves us none but hydracids. All saline compounds are brought to one formula, or rather salts are abolished, and we have only binaries; for the bodies regarded as salts become the analogues of chloride of sodium.

"We are tempted to adopt this theory, or at least to remain undecided between it and the theory of Lavoisier.

"Nevertheless, reflection shows us two motives that repel this system; motives so powerful, that to me they appear decisive.

"The first objection is, that it is necessary to admit the existence of a number of bodies that we have never seen, and which we need never expect to see—per-sulphuric acid, per-nitric acid, per-carbonic acid, &c. In a word, every oxacid would presume the existence of another compound containing one extra proportion of oxygen. Now, I declare, that whenever a theory requires the admission of unknown bodies, we ought to distrust it. We ought to give no assent to it, except with the greatest reserve. We should not assent until it is impossible to abstain from doing so, or at least we should assent only in presence of the most pressing analogies. The more a theory gives origin to imaginary bodies, the more we should control our credence. By acting otherwise, we should fall back into the inconveniences of phlogiston; and, in this case, we should not have merely one phlogiston to trouble us, we should have a cloud of phlogistons. The unknown compounds would be nearly as numerous as the known compounds; and thence would arise a confusion and embarrassment for science to which we ought not to resign ourselves, except in obedience to a real and imperative necessity.

"There is another reason which augments the improbability of these hypotheses. Recently, it has been shown that phosphoric acid, dissolved in water, can assume three different states, in each of which it manifests peculiar properties. In fact, it forms three distinct hydrates—

$$Ph^2O^5{,}3H^2O—Ph^2O^5{,}2H^2O—Ph^2O^5{,}H^2O.$$

The first of these hydrates has received the name of common phosphoric acid; the second, of pyrophosphoric acid; and the third, of metaphosphoric acid. These three acids produce three different sorts of salts, in which the water originally combined with the acids, is replaced by bases, atom for atom, either partially or totally. Moreover, the three varieties of acid pass readily from any one condition into the others, either from loss of water by calcination, or from gain of water by prolonged contact with that liquid. There consequently exists, on the one hand, incontestable differences among them, and on the other hand, indications of great natural resemblances. The simple formulæ commonly assigned to these acids, exhibiting differences which we may compare to those that exist between alcohol and ether, present an intelligible account of their common features of agreement. But if, instead of considering these compounds as hydrates of the same oxacid, we treat them as different hydracids, the formulæ become—

$$Ph^2O^8{,}H^6—Ph^2O^7{,}H^4—Ph^2O^6{,}H^2.$$

Here we perceive grave changes in nature for bodies that pass so easily from one state to the other. We admit differences in composition of the first importance to explain differences in properties of very secondary importance. The effect is by no means in proportion to the cause.

"I insist upon these arguments, because I can find no others to oppose to the system maintained by Davy and Dulong. The question is therefore not decided. It is possible that this theory may suddenly rise triumphant, supported by some discovery of a nature to give it new force. But at present, I think it should be rejected, because of that innumerable multitude of imaginary compounds which it calls into existence. If I could see only a part of these compounds, I should have less reluctance to believe in the existence of the rest."

In this passage Dumas ascribes the binary theory of salts to Davy, into whose mouth he puts a speech, which would doubtless have astonished the Fellows of the Royal Society, unused as they are to theatrical displays. I have looked in vain through Davy's work to find the challenge which Dumas ascribes to him. Most chemists who have discussed this subject, since Dumas published the remarks which I have quoted, refer to Davy as the originator of the binary theory, but neither Graham, nor Kane, nor Miller, quote, or even refer to, the terms in which Davy set forth his doctrine. The following passages are the most explicit on this subject that I can find in Davy's works.

"It appears that this new substance [one of the gaseous compounds of chlorine and oxygen], though it contains four proportions of oxygen, is not an acid; and hence it is probable, that the acid fluid compound of oxygen, chlorine, and water, which M. Gay Lussac calls chloric acid, owes its acid powers to combined hydrogen, and that it is analogous to the other hyperoxymuriates [chlorates], which are triple compounds of inflammable bases, chlorine, and oxygen, in which the base and the chlorine determine the character of the compound. Muriate of potassa is a perfectly neutral body; and when six proportions of oxygen are added to it, it still remains neutral. Muriatic acid (chlorine and hydrogen) is a strong acid; and according to the relation above stated, it ought not to lose its acid powers by the addition of six proportions of oxygen. Till a pure combination of chlorine and oxygen is obtained, possessed of acid properties, we have no right to say that chlorine is capable of being acidified by oxygen, and that an acid compound exists in the hyperoxymuriates. We know that chlorine is capable of being converted into an acid by hydrogen, and, as I mentioned in my last paper, where this principle exists, its energies ought not to be overlooked; and all the new facts confirm an opinion which I have more than once before submitted to the consideration of the Society, namely, that acidity does not depend upon any *peculiar* elementary substance, but upon *peculiar combinations* of various substances." *Phil. Trans.*, read May 4, 1815.

"I have discovered a gaseous combination of four proportions of oxygen, and one of chlorine, which has no acid properties. M. Gay Lussac has discovered a compound of two proportions of hydrogen, one of chlorine, and six of oxygen, which has acid properties; but he considers this substance merely as chlorine acidified by oxygen, and neglects the hydrogen, without which, however, he allows it cannot exist. He supposes that this acid of one proportion of chlorine and five of oxygen, exists in all the hyperoxymuriates, but he does not support his supposition by any proof. The hyperoxymuriates are, as I showed six years ago, composed of one proportion of chlorine, one of a basis, and six of oxygen. Hydrogen, in M. Gay Lussac's chloric acid, may be considered as acting the part of a base; and it is an important circumstance in the law of definite proportions, that when one metallic or inflammable basis combines with certain proportions of a compound, all others combine with the same proportions.

"M. Gay Lussac states, that if chloric acid be not admitted as a pure combination of chlorine and oxygen, neither can the nitric or sulphuric acids be admitted as pure combinations of oxygen. This is perfectly obvious. An acid composed of five proportions of oxygen and one of nitrogen is altogether hypothetical; and it is a simple statement of facts to say that liquid nitric acid is a compound of two proportions of hydrogen, one of azote, and six of oxygen; and, as I showed long ago, the only difference between nitre and hyperoxymuriate of potash is, that one contains a proportion of azote, and the other a proportion of chlorine.

"There are very few of the substances which have always been considered as neutral salts, that really contain the acids and the alkalies from which they are formed. The muriates and fluates must be admitted to contain neither acid nor alkaline bases. Most of the prussiates, M. Gay Lussac has lately shown, are in the same case. Nitric and sulphuric acids cannot be procured from nitrates and sulphates without the intervention of some body containing hydrogen; and if nitrate of ammonia were to be judged of from the results of its decomposition, it must be regarded as a compound of water and nitrous oxide.

"Only those acids which are compounded of oxygen and inflammable bases appear to enter into combination with the fixed alkalies and alkaline earths without alteration, and it is impossible to define the nature of the arrangement of the elements in their neutral compounds. The phosphate and carbonate of lime have much less the character attributed to neutro-saline bodies than calcane (muriate of lime), and yet this last body is not known to contain acid or alkaline matter. The chloriodic acid, the phosganic acid, and the binary acids containing hydrogen, combine with ammonia without decomposition, but they appear to be decomposed in acting upon the fixed alkalies or alkaline earths; and yet the solid substances they form have all the characters which were formerly regarded as peculiar to neutral salts, consisting of acids and alkalies, though they none of them contain the acids, and only the two first of the series the alkalies, from which they are formed.

"The substitution of analogy for fact is the bane of chemical philosophy; the legitimate use of analogy is to connect facts together, and to guide to new experiments."—*On the Constitution of Acids.* Journal of Science and the Arts (1816), Vol. I. art. xviii.

These passages show that Davy disputed the doctrine that *salts consist of acids and bases*, but they cannot be said to show, that he formally and explicitly recommended any other doctrine. He confines himself to statements of the ultimate composition of salts. He does not say, as Dumas and his later commentators make him say, that *the oxygen of a salt is all combined with the acid radical*, that nitre is $K+NO^6$, and that chlorate of potash is $K+ClO^6$. What he says is, that chlorate of potash is $Cl^1+K^1+O^6$, that nitre is $N^1+K^1+O^6$, that liquid nitric acid is $H^2+N^1+O^6$. He thus makes two proportions of hydrogen equivalent to one proportion of potassium. He says also that the chlorates are *triple* compounds, *not* that they are *binary* compounds of $K+ClO^6$. It is, however, to this paper of Davy's, on the Constitution of the Acids, that Gmelin[1] refers, as containing his suggestion of the binary theory of salts, and I have failed to find any more explicit statement elsewhere in

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[1] Handbook of Chemistry, ii. 15.

Davy's works. It consequently appears to me that Davy had no specific theory in his mind, and that his main intention was to dispute the accuracy of M. Gay Lussac's proposition, that chlorine could be acidified by oxygen; but at any rate his views, as expressed in these quotations, differ essentially from those subsequently published by Dr. Clark and myself, and which have been appropriated and claimed by Mr. Gerhardt. Davy certainly did not *double the atomic weight of oxygen* so as to reduce the total number of atoms of oxygen contained in the chlorates and nitrates from six to three, nor did he show that the acids corresponding to these salts contained *a single atom of hydrogen* as base and no water, nor that the hydrate of potash contained *a single atom of hydrogen* and no water. The peculiar theory of hydration first published by Dr. Clark, afterwards developed by myself, and now claimed by Mr. Gerhardt, is consequently a different theory from that suggested by Davy and discussed by Dumas. I have not seen the paper published by Dulong.

After discussing Davy's theory of the salts, M. Dumas proceeded to discuss another theory, which, he says, is due to M. Longchamp. I do not know where the original is to be found, and cannot tell whether or not M. Longchamp's theory is explained fairly. But here is M. Dumas' account of it, written in terms which I presume were intended to encourage M. Longchamp in the pursuit of science.

"We have seen," he says,[1] "that Davy, in adjusting the composition of the salts, took the oxygen of the base to add it to that of the acid.[2] M. Longchamp has inverted that process. He wishes us to carry from the acid to the base as much oxygen as that which it already contains. According to him, sulphuric acid and protoxide of lead, combine to produce a compound of sulphurous acid and brown oxide of lead, the formula of which ought to be written thus—SO^2,PbO^2. The sulphuric acid of commerce becomes a combination of sulphurous acid and oxygenated water: SO^2,H^2O^2. This is therefore the hypothesis of Davy turned topsy-turvy.

"According to this plan, if you take sulphate of sesquioxide of manganese, which is represented by $3SO^3,Mn^2O^3$, you are to see in it what is indicated by the formula $3SO^2,Mn^2O^6$. After this transformation, you perceive that you have a very strong acid, the manganic acid, playing the part of base *vis-à-vis* to a very weak acid, the sulphurous acid; and, above all, that these are two acids which cannot exist together, since sulphurous acid reduces manganic acid to the state of protoxide of manganese.

"Again,—suppose you have sulphate of alumina. That salt is no longer $3SO^3,Al^2O^3$, it is become $3SO^2,Al^2O^6$. Here behold Al^2O^6, a compound that nobody knows, and the existence of which has never been suspected. There would be a multitude of similar changes; for it would be necessary that every salifiable oxide had a corresponding oxide containing double the quantity of oxygen, while for each acid susceptible of combination with bases, it would be necessary to find another compound possessing an atom of oxygen less. We should be forced to admit the existence of FeO^2, FeO^6, Gl^2O^6, MgO^2, KO^2, &c., &c., and of Ph^2O^4, Ph^2O^2, &c.

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[1] Leçons sur la Philosophie Chimique, 8vo. Paris, 1837, p. 344.

[2] It would be just as accurate to say that he took the oxygen of the acid to add it to that of the base.—J. J. G.

"It is useless to insist further on the improbabilities of this theory, so much less happy than that of Davy, and which presents nothing philosophical."

I shall not dwell on the sarcastic style, but consider the substance of this criticism.

According to Dumas, it is monstrously absurd to suppose that sulphate of lead contains sulphurous acid and brown oxide of lead. It is monstrously absurd to suppose that oil of vitriol contains sulphurous acid and oxygenated water. According to Dumas, you ought to crucify at the Sorbonne the man who proposes things so improbable and so unphilosophical. But let us appeal from rhetoric to facts:—

"The peroxide of lead gives rise to some peculiar and remarkable reactions;—sulphurous acid converts it instantly into sulphate of lead. There is even ignition at the moment of combination." DUMAS, *Traité de Chimie* (Liége, 1848), tom. III., p. 401.

"Scarcely is sulphurous acid brought into contact with peroxide of hydrogen, even diluted with much water, when its odour disappears, and it passes into the state of sulphuric acid."—THENARD, *Traité de Chimie*, (Paris, 1827), tom. II, p. 87.

The exact opposition of the facts to the rhetoric renders comment unnecessary.

Dumas's other examples are equally extravagant. The formula of the sulphate of sesquioxide of manganese, $3SO^3,Mn^2O^3$ is, as he admits, a thing of "convenience," not the representation of a fact. As a mere hypothesis, it is liable to be dealt with unceremoniously. I shall show in the course of this inquiry, that the quantity of manganese contained in this salt, in combination with 3 atoms of sulphur, is not 2 atoms, but 3 atoms of manganese; that the quantity of oxygen is not 12 atoms but 6 atoms; that the ultimate elements are therefore, $S^3Mn^3O^6$, which formula divided by 3, gives $SMnO^2$, or according to the despised theory of M. Longchamp, $MnO+SO$, in which *we have not*, as M. Dumas affirmed, "a very strong acid, the manganic acid, playing the part of base *vis-à-vis* to a very weak acid, the sulphurous acid." We have no manganic acid at all. We have an oxidised basic radical, MnO, combined with an oxidised acid radical, SO, and we can actually produce $MnO+SO$, the sulphate of manganese, by heating MnO with hydrated SO. M. Dumas's ridicule is therefore entirely misplaced.

The same remarks apply to the tersulphate of alumina, the proper formula for which, as I shall show elsewhere, is $AlcSO^2$, or $AlcO,SO$.

The question of the constitution of the salts might be conveniently discussed in reference to any one of them. We might select oil of vitriol, and inquire, shall we write this compound $HO+SO^3$, according to Lavoisier, or $H+SO^4$, according to the binary theory? or, shall we double the atomic weight of oxygen, and write it $H+SO^2$, according to the binary theory, or $HO+SO$, according to the theory ascribed to Longchamp? It appears to me, and I hope to bring the readers of this essay to my opinion, that the doubling of the atomic weight of oxygen is absolutely essential, and that consequently one of the last two formulæ must be adopted as the truest representation of the composition of oil of vitriol; but it does not seem to be possible, either by experiment or by argument, to determine, whether the two atoms of oxygen are combined, both with the acid radical, or one with each of the radicals. I think it *probable* that the latter is the case, but there is no evidence to prove it; and we are consequently at liberty to use either the formula H,SO^2, or the formula HO,SO, according as one or the other may best answer a given purpose.

The chemists who have discussed the constitution of salts, since M. Dumas published his lectures, have, with the exception of M. Gerhardt, confined themselves to the single case discussed by Dumas, of $HO+SO^3$ *versus* $H+SO^4$. They have not considered the important effects that result from the adoption of Dr. Clark's proposal to double the atomic weights of oxygen and carbon. It seems, therefore, to be unnecessary to quote either their arguments or conclusions, which do not, in the main, differ from those of Dumas. The theory of Lavoisier is "permitted" to remain in fashion because the existing race of chemists, though aware of its fallacies, and suffering from its defects, want the courage to overthrow it, or the ability to organise a better.

The Radical Theory.

The principles of the Radical Theory may be stated in a few words:—

Every salt is composed of two radicals, simple or compound, oxidised or not oxidised.

Every element can act as a radical, except oxygen. Oxygen never acts as a simple radical, nor forms part of a compound radical. Some of the metallic elements form two radicals, which differ in weight and properties.

Compound radicals consist of (1) carbon and hydrogen, or (2) carbon and nitrogen, or (3) combinations of other elements, with the foregoing. For the most part, and when not otherwise expressed, the arguments in the following pages refer to radicals that contain carbon and hydrogen only.

The quantity of an element which constitutes a radical is an atom, or as much as forms a single volume of gas.

The quantity of a compound which constitutes a radical is as much as forms a single volume of gas. When the compound is not gaseous, the radical quantity is as much as is equivalent to a single volume of hydrogen or of chlorine.

Every gaseous salt measuress two volumes, which is the measure of its two radicals. When salts contain oxygen, that element adds to their weight, but not to the measure of their gas.

Though a compound radical that measures one volume in the state of gas, still measures one volume when combined with one or more atoms of oxygen, the oxygen is not to be considered as a constituent part of the radical, but only as an addition to it.

Muriatic acid, HCl, may be taken as the model of a salt. Any basic radical, simple or compound, may replace H, and produce a chloride = MCl, such as chloride of potassium = KCl, or chloride of methyl = CH^3,Cl. Any acid radical, simple or compound, may replace Cl, and produce another hydride, such as HBr, HS, or H,C^6H^5.

When either or both radicals are oxidised, the compound is an oxygen salt. It is in all cases impossible to determine whether the oxygen of a salt is combined exclusively with either of the two radicals, or divided, equally or unequally, between them. In framing equations for the purpose of explaining theoretical opinions respecting the constitution or transformations of compounds, we may place the oxygen in that manner which best answers our special intention; but in the construction of formulæ for purposes of classification or nomenclature, the oxygen should, in all cases, be put together at the end of the formulæ.

Since all gaseous salts that contain two radicals form two volumes of gas, whether the radicals are simple or compound, oxidised or not oxidised, it is assumed, that every compound radical, if isolated and brought into the gaseous state, would measure one volume. In justification of this assumption, it may be added, that every compound radical that has yet been isolated measures one volume, and is the equivalent of one volume of hydrogen or of chlorine.

Salts combine with one another, so as to form double, triple, quadruple, and other forms of compound salts.

Classification of Oxygen Salts.

Referring to the classification of oxygen salts, which I published in 1834 (see page 15), I have to remark, that that system requires scarcely any amendment, to adapt it to the Radical Theory of 1856.

A. SIMPLE SALTS.

CLASS I. $M+RO$ is an important class of salts, comprehending water H,HO; the protoxides, K,KO; their hydrates, K,HO; many organic compounds, such as alcohol, H,C^2H^5O, and ether, C^2H^5, C^2H^5O; the silicates, M,SiO; the borates, M,BO; and such compounds as chlorosulphuric acid, $ClSO$, and the oxychloride of chromium, $CrClO$.

CLASS II. $M+RO^2$, the rational formula for which may possibly be $MO+RO$, comprehends the sulphates, oxalates, nitrites, chlorites, and most of the salts of organic acids, such as the acetates, formiates, benzoates, valerianates, &c.

CLASS III. $M+RO^3$. Rational formula, probably $MO+ROO$. The nitrates, chlorates, iodates, bromates, metaphosphates, and several salts of compound organic radicals. I am also disposed to put into this class many of the anhydrides, such as anhydrous sulphuric acid $=S+SO^3$, or $SO+SOO$; anhydrous acetic acid $=C^2H^3+C^2H^3O^3$, or $C^2H^3O+C^2H^3OO$; anhydrous benzocinnamic acid $=C^7H^5+C^9H^7O^3$, or $C^7H^5O+C^9H^7OO$.

CLASS IV. $M+RO^4$. Perchlorates.

B. DOUBLE SALTS.

CLASS V. $MM+RO^3$. Probable composition, $MO,RO+MO$. The salts of this class are bibasic, because the acid radical is indivisible.

Examples:—

$KK; CO^3$ . .	Neutral carbonate of potash.
$KH; CO^3$ . .	Bicarbonate of potash.
$CaMg; CO^3$.	Bitterspar.

The compound of sulphuric acid with peroxide of hydrogen, belongs to this class, $HO,SO+HO=HH; SO^3$.

CLASS VI. $M+R^2O^3$. Probable composition, $MO,RO+RO$. As the salts of Class V are basic salts of Class II, so the salts of this class are acid salts of Class II.—the relations of the three kinds being as follows:—

Class V.	MO,MO,RO.
,, II.	MO,RO.
,, VI.	MO,RO,RO.

The hyposulphates belong to this class.

CLASS VII. $M^2+R^2O^3$. Probable composition, $MO,RO+M,RO$; namely, a compound of a salt of Class I. with a salt of Class II. The sulphites belong to this class, the salts of which, like those of Class V., are necessarily bibasic:—

$KK; S^2O^3$ . .	Neutral sulphite of potash.
$KH; S^2O^3$ . .	Bisulphite of potash.
$KNa; S^2O^3$ . .	Sulphite of potash and soda.

It has been erroneously assumed that the carbonates and sulphites are of similar constitution: they are both bibasic, and both contain 3 atoms of oxygen; but with those relations the similarity ends. The carbonates contain one acid radical, and the sulphites contain two acid radicals; so that their constitution is essentially different.

CLASS VIII. M^3+RO^4. Probable composition, $MO,ROO+M,MO$. Example: the terbasic phosphates.

The full discussion of the composition of these, and other classes of salts, will take place in subsequent sections.

In order to develop the Radical Theory in the shortest and clearest manner, I have arranged the facts upon which I propose to found my arguments in the form of Tables, to which I shall add a running Commentary.

I shall first bring under your notice, a Table of the Atomic Weights, or Chemical Equivalents, of the Elements. Secondly, a Table containing Examples of Compound Organic Radicals and Salts which contain them. Thirdly, a Table of Gases and Vapours. After explaining these Tables, I shall apply the facts they contain to the explanation and illustration of some problems of general chemical interest. These applications must necessarily be restricted in number, because I do not propose to write a system of chemistry, but only an account of certain philosophical principles, and I shall limit the examples to such as afford the illustrations requisite for the establishment of those principles.

Atomic Weights of the Elements.

ELEMENTS.		Griffin.	Miller.	Abridged Names.[1]
Aluminum	Al	13.65	13.7	Al– ous.
—	Alc	9.1		Al– ic.
Antimony	Sb	129.	129.	Stib– ous.
—	Sbc	43.		Stib– ic.
Arsenic	As	75.	75.	Ars– ous.
—	Asc	25.		Ars– ic.
Barium	Ba	68.5	68.5	Baryt.
Bismuth	Bi	213.	213.	Bism– ous.
—	Bic	71.		Bism– ic.
Boron	B	3.6	10.9	Bor.
Bromine	Br	80.	80.	Brom.
Cadmium	Cd	55.7	55.7	Cadm.
Calcium	Ca	20.	20.	Calc.
Carbon	C	12.	6.	Carb.

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[1] The use of these abridged names will be explained in the section on Nomenclature.

ELEMENTS.		Griffin.	Miller.	Abridged Names.
Cerium	Ce	46.	46.	Cer– ous.
—	Cec	30.66		Cer– ic.
Chlorine	Cl	35.5	35.5	Chlor.
Chromium . . .	Cr	27.	26.3	Chrom– ous.
—	Crc	18.		Chrom– ic.
Cobalt	Co	29.5	29.5	Cob– ous.
—	Coc	19.7		Cob– ic.
Copper	Cu	64.		Cupr– ous.
—	Cuc	32.	31.75	Cupr– ic.
Didymium . . .	D	48.	48.	Didym.
Erbium	E			Erb.
Fluorine	F	19.	19.	Fluor.
Glucinum . . .	G	4.7	7.	Gluc.
Gold	Au	196.5	196.6	Aur– ous.
—	Auc	65.5		Aur– ic.
Hydrogen . . .	H	1.	1.	Hydr.
Ilmenium . . .	Il			Ilm.
Iodine	I	127.	127.	Iod.
Iridium	Ir	99.	98.6	Irid– ous.
—	Irc	66.		Irid– ic.
Iron	Fe	28.	28.	Ferr– ous.
—	Fec	18.66		Ferr– ic.
Lantanium . . .	La	46.	46.	Lant.
Lead	Pb	104.	103.6	Plumb.
Lithium	L	6.5	6.5	Lith.
Magnesium . . .	Mg	12.	12.16	Magn.
Manganese . . .	Mn	27.6	27.6	Mang– ous.
—	Mnc	18.4		Mang– ic.
Mercury	Hg	200.		Mer– ous.
—	Hgc	100.	100.	Mer– ic.
Molybdenum . .	Mo	46.	45.	Molybd– ous.
—	Moc	15.33		Molybd– ic.
Nickel	Ni	29.55	29.5	Niccol– ous.
—	Nic	19.7		Niccol– ic.
Niobium	Nb			Niob.
Nitrogen	N	14.	14.	Nitr.
Osmium	Os	99.	99.4	Osm– ous.
—	Osc	66.		Osm– ic.
Oxygen	O	16.	8.	Ox.
Palladium . . .	Pd	53.2	53.2	Pall– ous.
—	Pdc	26.6		Pall– ic.
Pelopium . . .	Pe			Pelop.

ELEMENTS.		Griffin.	Miller.	Abridged Names.
Phosphorus . . .	P	31.	31.	Phosph.
Platinum . . .	Pt	99.	98.6	Plat– ous.
—	Ptc	49.5		Plat– ic.
Potassium . . .	K	39.	39.	Potass.
Rhodium . . .	Rh	52.	52.2	Rhod– ous.
—	Rhc	34.66		Rhod– ic.
Ruthenium . . .	Ru	52.	52.	Ruth– ous.
—	Ruc	34.66		Ruth– ic.
Selenium . . .	Se	40.	39.6	Sel.
Silicon	Si	7.5	14.24	Sil.
Silver	Ag	108.	108.	Argent.
Sodium	Na	23.	23.	Natr.
Strontium . . .	Sr	44.	43.8	Stront.
Sulphur	S	16.	16.	Sulph.
Tantalum . . .	Ta			Tant.
Tellurium . . .	Te	64.	64.	Tellur– ous.
—	Tec	32.		Tellur– ic.
Terbium	Tb			Terb.
Thorinum . . .	Th	59.5	59.5	Thor.
Tin	Sn	59.	58.8	St– ous.
—	Snc	29.5		St– ic.
Titanium . . .	Ti	12.	24.2	Tit.
Tungsten . . .	W	92.	92.	Tungst.
Uranium	U	60.	60.	Ur– ous.
—	Uc	40.		Ur– ic.
Vanadium . . .	V	68.4	68.5	V– ous.
—	Vc	22.8		V– ic.
Yttrium	Y			Yttr.
Zinc	Zn	32.5	32.5	Zinc.
Zirconium . . .	Zr	22.4	33.6	Zirc.

Atomic Weights of the Elements.

By the term *atomic weight*, I mean a chemical combining proportion. By the term *equivalent* I mean the same thing. I set aside all physical and metaphysical speculations respecting the nature of matter and atoms. I mean by *atom* only a chemical combining quantity. I acknowledge no equivalent that differs from an atom.

To put this principle into practice, that is to say, to act upon the principle that atoms and equivalents are alike, I assume that the atomic weights of oxygen, hydrogen, nitrogen, and chlorine, are represented by the specific gravities of their gases. In other words, that one volume of each of these elements in the state of gas, is one atom or one equivalent.

This method of determining what constitutes an atom depends upon Gay Lussac's discovery, that gases combine in equal volumes. Assuming that volumes represent atoms, the different densities of the elementary gases give the relative weights of the atoms. All theories and all equivalents incompatible with this assumption are sacrificed. There can be no compromise between this and other theories. The half-measures adopted years ago by Berzelius—such as the crossed atoms of the metalloids, the construction of sesquioxides, and other similar expedients—have proved useless. I propose then to abandon half measures, and to bring equivalents and atoms into strict harmony; to set aside, for the moment, a variety of common chemical hypotheses respecting crossed atoms, sesquioxides, anhydrous acids, anhydrous bases; peroxidation and protoxidation;—and, dispensing with these hypotheses, and looking at the facts of chemistry from another point of view, I propose to examine whether it is not possible to free our theories from some of their present complications.

If a single volume of oxygen and of hydrogen represents an atom of each, it follows that an atom of water contains two atoms of hydrogen and one atom of oxygen. Is water really so constituted? That is the fundamental problem in theoretical chemistry, and until that problem is solved, no other important theoretical problem, no difficulty respecting radicals, or salts, or acids, or bases, or hydrates, or ethers, or alcohols, can be considered as being finally disposed of. For this reason much of what I have to say in this essay, will bear, directly or indirectly, upon that single point.

We have at present four theories of the constitution of water. First, the common English theory, that it contains one atom of hydrogen and one atom of oxygen. Secondly, Berzelius's theory, that it contains two atoms of hydrogen combined *directly and together*, with one atom of oxygen. Thirdly, Gerhardt's theory, that it contains two atoms of hydrogen combined *separately, but equally*, with one atom of oxygen. And, fourthly, Clark's theory, that water contains *one atom of* HYDROGEN, *combined with one atom of* OXIDE OF HYDROGEN. The evidence in support of this view, will be brought forward in a succeeding chapter, but in the meantime I assume—theoretically and subject to future discussion—that *water is a compound of two radicals, one of them oxidised, and the other not oxidised, its formula being* H,HO. If the facts that I have to bring forward in favour of this theory be considered valid, one effect will be to remove the difficulty in the way of assimilating equivalents to atoms, a difficulty which is inseparable from the theory, that the gaseous atom of hydrogen has twice the volume of the gaseous atom of oxygen. The atomic weights in my table are based upon the principle that one volume of each of these elements is equal to one atom. Every number in the table represents as much of a given element as, in my opinion, is chemically equivalent to one volume of hydrogen, and every symbol is consequently equal to one H.

The Table contains, as a standard of comparison, the atomic weights of Professor Miller (the latest published in England), where hydrogen is 1. The atomic weights, or equivalents, which I propose to adopt, are placed in juxta-position with these. On comparing the two scales, we find, that the weights of the metalloids, and of the alkaline metals, remain unaltered, but that oxygen is made 16 instead of 8, and carbon 12 instead of 6. These alterations are made in the usual atomic weights of carbon and oxygen, in order that the constitution of the protoxides, and the hydrates of the protoxides, may be assimilated to that of water, according to the general formula, M,MO.

I come now to describe a great divarication from prevalent systems. I propose to adopt, for some of the acidifiable metals, and for the elements that produce the compounds commonly termed sesquioxides,—two atomic weights—two equivalents—*two quantities*, EACH CHEMICALLY EQUIVALENT *to one atom of hydrogen*. This proposal is, of course, founded upon Mr. Gerhardt's suggestion of double equivalents, a suggestion of great importance, and deserving of more attention than chemists have yet bestowed upon it. Twenty years ago, when I reduced the formulæ of alumina, silica, and boracic acid, from Al^2O^3, SiO^3, and BO^3, to Al^2O, Si^2O, and B^2O, in order that they might agree with other protoxides, I halted at the red oxide of iron, because a similar reduction of Fe^2O^3 to Fe^2O, gave a formula that was incompatible with that of the ferrous oxide, and inconsistent with that part of the atomic theory which is called *the law of combination in multiple proportions.* Mr. Gerhardt, coming to the same difficulty, cut the gordian knot, which, like me, he was unable to untie, and, boldly disregarding the law of multiple proportions, advocated the adoption of double equivalents. After a careful consideration of the bearings of this proposal, I have come to the conclusion that Mr. Gerhardt is in the right, except in the following particular: while he adopts *two equivalents* for one metal, he still retains *one atomic weight*, and he seems simply to intimate that the two equivalents are different proportions of the same kind of metal. He says—"When we speak of *the equivalent* of a body, we should always indicate to what other body, to what functions, to what properties, that equivalent corresponds."[1] Now, I hold the opinion, that when the change in the *atomic weight* occurs, a change takes place simultaneously in the *quality* of the atom; so that, for example, the mercuric atom is not merely of half the weight of the mercurous atom, but is endowed with different chemical properties, and capable of producing compounds which also differ in properties from the compounds of the mercurous atom; so, also, that the ferric atom is not merely two-thirds of the quantity of iron that is contained in the ferrous atom, but is a different chemical agent, possessing properties that are peculiar to irself, and not the same as the properties of the ferrous atom. The characteristics of the ferrous and ferric atoms do not, on this view, depend upon their relations to other bodies, nor upon the equivalents of other bodies, but are inherent and not conditional properties. Each is a single complete *chemical atom*, and neither of them is an *equivalent* in any other sense.

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[1] Introduction to Unitary Chemistry, p. 78.

By the adoption of double equivalents, we get rid of the complicated formulæ and the perplexities that encumber all theories of the constitution of the salts of those metals that give *two series*—such as the ferrous and ferric salts of iron, and the mercurous and mercuric salts of mercury, &c.; above all, we get rid of the hypothetical SESQUIOXIDES. I say *hypothetical*, because I consider them to be the creatures of a fiction. I do not believe in their existence. I know the *red oxide of iron*. That is a reality. But the *sesquioxide of iron* is a mere phrase, a technical term which expresses a particular hypothesis. It has only an arithmetical existence, and vanishes when you adopt a different calculation.

I propose then, in the case of iron,—and I take that metal as an example of the entire class of elements that produce sesquioxides,—to have *two atomic weights—two equivalents*. One of these atoms, weighing on the hydrogen scale 28, is the radical of the *ferrous* salts, and I mark it Fe. The other atom, weighing 18·66, or two-thirds of the first atom, is the radical of the *ferric* salts, and I mark it Fec. The atoms Fe and Fec are each equivalent to one another, and to one atom of hydrogen, each capable of combining with one atom of chlorine; and consequently their oxides, hydrates, and chlorides, should be indicated by corresponding formulæ:—

Ferrous Compounds.		*Ferric Compounds.*	
Fe,FeO	Ferrous oxide.	$Fec,FecO$	Ferric oxide.
H,FeO	Hydrate of Ferrous oxide.	$H,FecO$	Hydrate of Ferric oxide.
$FeCl$	Ferrous chloride.	$FecCl$	Ferric chloride.
$FeCy$	Ferrous cyanide.	$FecCy$	Ferric cyanide.

The elements for which I propose to adopt two equivalents are the following: aluminum, antimony, arsenic, bismuth, cerium, chromium, cobalt, copper, gold, iron, manganese, mercury, molybdenum, nickel, platinum, and the other metals of that series, tellurium, tin, uranium, and vanadium.

I propose to distinguish the two atoms of the same element by calling the heavier the *basylous* atom, and the lighter the *basylic* atom, and by adding to the symbol of the basylic atom the letter c. Thus,—

Au = Aurous atom.
Auc = Auric atom.
Hg = Mercurous atom.
Hgc = Mercuric atom.
Mn = Manganous atom.
Mnc = Manganic atom.
Cu = Cuprous atom.
Cuc = Cupric atom.

This nomenclature is borrowed from the system proposed some years ago by Berzelius, and used by Mr. Watts in his translation of *Gmelin's Handbook of Chemistry*.

Of course, this theory is, to a certain extent, inconsistent with the atomic theory, and especially with the doctrine of combination in multiple proportions. That theory assumes that each element has a single atomic weight, and that the single atom combines with other elements in multiple proportions. Two atoms of iron, with three of oxygen, or with three of chlorine, and so on.

My view of the matter is as follows:—The element iron can, under different circumstances, form *two molecules*, differing from one another in weight, and in all those physical properties that depend upon the quantity of ponderable matter, but agreeing with one another in having the same chemical power, in being each a chemical equivalent, in exercising the functions of a complete single atom; the chemical properties of one equivalent and of its salts being, at the same, time quite different from those of the other equivalent.

Nothing is easier than to produce compounds either of the ferrous or the ferric atom, to convert either into the other, to combine either with oxygen, or sulphur, or chlorine, or to make either of them pass into salts, both organic and inorganic. In all these circumstances each atom is chemically equivalent to the other. The two chemical atoms of iron can be treated like atoms of two different metals. Their atomic weight is different, and they produce compounds having different properties, and but for the circumstance that they are both known to be iron, and can be easily converted from one condition into the other, they might be taken for two different elements. Their compounds differ from one another as much as the salts of cobalt do from those of nickel, or the salts of barium from those of strontium. I shall examine a few of these transformations of iron, because, next to the constitution of water, this question of double equivalents of the metals is the most important theoretical point that can occupy our attention. I hope, by a complete elucidation of this subject, to dispel what I must call the illusion that there is something in the nature of *equivalents* which renders them different from atoms. These two words have, or ought to be held to have, under all circumstances, the same meaning.

If we dissolve iron in diluted hydrochloric acid, hydrogen is set free, and we obtain *ferrous* chloride:—

$$HCl + Fe = FeCl + H.$$

If we combine ferrous chloride with half as much chlorine as it already contains, we produce *ferric* chloride. According to the atomic theory, this transformation is explained as follows:—

$$2\mathrm{FeCl}+\mathrm{Cl} = \mathrm{Fe}^2\mathrm{Cl}^3.$$

Two compounds, each containing one atom of iron and one atom of chlorine, are decomposed, another atom of chlorine is taken up, and a new compound is formed in which two atoms of iron are combined directly with three atoms of chlorine—

$$(\mathrm{Fe}+\mathrm{Fe}) + (\mathrm{Cl}+\mathrm{Cl}+\mathrm{Cl}).$$

This explanation is completely at variance with the electro-chemical theory, and it is fallacious in a strictly chemical point of view. The fallacy lies in this, that *only a part of the change that takes place* is accounted for, while the equation pretends to account for the entire change. The increase in the quantity of chlorine which is taken up by the iron, is by no means the whole change that takes place in this transformation. The iron goes into the new compound, not merely in that increased quantity which is held to be a multiple proportion, but changed in its chemical nature. The perchloride of iron differs essentially in its chemical reactions from the protochloride of iron. The perchloride of iron, therefore, does not contain a multiple proportion of *the same iron* that is contained in the protochloride of iron, but it contains a *different chemical substance;* and strict logic demands that that different chemical substance should be admitted to be different, and that the difference should be denoted by a different chemical name. The doctrine of combination in multiple proportions, takes no cognisance of the change that occurs in the chemical properties of metals, when they enter into combination in what are called multiple proportions. It simply points out the physical condition of change in weight. This appears to me to be a radical defect in this important law of the atomic theory.

The explanation of this process of the conversion of protochloride of iron into perchloride, in accordance with the proposed theory of double equivalents, is as follows:—

$$\begin{array}{rcl} \mathrm{FeCl} & & \mathrm{FecCl}. \\ \mathrm{FeCl} & = & \mathrm{FecCl}. \\ \mathrm{Cl} & & \mathrm{FecCl}. \end{array}$$

[illegible]

combining with 3 [illegible]

The free chlorine converts two ferrous atoms into three ferric atoms; in other words, two chemical equivalents of one description of iron become three chemical equivalents of another description of iron; and *since every chemical equivalent of iron, whether ferrous or ferric, requires one equivalent of chlorine to form a chloride,* the two equivalents of ferrous chloride require, after the transformation, a third equivalent of chlorine, and produce three equivalents of ferric chloride. Here we distinctly perceive the change that occurs in the number of atoms of the iron, and that there is a corresponding change in the *chemical nature* of the iron, can be made abundantly manifest by the action of every suitable chemical reagent. As to the theory of combination in multiple proportions, there is here no evidence in support of it. The ferric chloride, or perchloride of iron, is on the theory of double equivalents, not a compound of a multiple quantity of iron with a multiple quantity of chlorine = Fe^2 with Cl^3, but, like the ferrous chloride, is a binary compound of two radicals :—

The ferrous chloride being Fe Cl.
The ferric chloride being FecCl.

This theory is in complete accordance with the electro-chemical theory.

Let us now examine what occurs in the well-known experiment of the reduction of perchloride of iron to protochloride by means of metallic copper, an analytical process of frequent use in the laboratory :—

$$\left.\begin{array}{l}\mathrm{FecCl}\\\mathrm{FecCl}\\\mathrm{FecCl}\end{array}\right\} + \mathrm{Cuc} = \begin{array}{l}\mathrm{FeCl.}\\\mathrm{FeCl.}\\\mathrm{CucCl.}\end{array}$$

Under the influence of the copper—a free basic radical—three ferric atoms become transformed into two ferrous atoms, and one atom of chlorine is given up to the cupric atom.

Thus, we perceive that when ferrous atoms are in presence of an excess of a free acid radical, they are resolved into ferric atoms, which can neutralize one-half more of the free acid radical, than can be neutralized by the ferrous atoms. Conversely, when ferric atoms are in presence of an excess of a free basic radical, they are resolved into ferrous atoms, giving up one-third of their acid radical to the free basic radical. An excess of an electro-positive substance, acting upon an electro-negative substance—or *vice versâ*—tends to produce an equality in the number of positive and negative equivalents. Thus, FeCl+FeCl+Cl produce FecCl+FecCl+FecCl, and FecCl+FecCl+FecCl+Cuc produces FeCl +FeCl+CucCl. The phenomena are precisely of the same character as many of the transformations of organic radicals, which take place when they are subjected to the action of chemical agents.

The following diagrams show what occurs in the PEROXIDATION of ferrous sulphate by means of hydrated nitric acid.

First, when no free sulphuric acid is present :—

Before.		*After.*	
$FeSO^2$		$FecSO^2$	Persulphate of iron.
$FeSO^2$	=	$FecSO^2$	Persulphate of iron.
HNO^3		FecHO	Hydrate of peroxide of iron.
		NO^2	Peroxide of nitrogen.

Two atoms of ferrous sulphate and one atom of hydrated nitric acid, produce two atoms of ferric sulphate, one atom of hydrated ferric oxide, and one atom of peroxide of nitrogen.

Secondly, when free sulphuric acid is present:—

$$\begin{array}{lcll}
\textit{Before.} & & \textit{After.} & \\
\begin{array}{l}\mathrm{FeSO^2}\\ \mathrm{FeSO^2}\\ \mathrm{H\,SO^2}\end{array} & = & \left.\begin{array}{l}\mathrm{FecSO^2}\\ \mathrm{FecSO^2}\\ \mathrm{FecSO^2}\end{array}\right\} & \text{Persulphate of iron.}\\
\mathrm{HNO^3} & & \mathrm{H\ \ HO} & \text{Water.}\\
 & & \mathrm{NO^2} & \text{Peroxide of nitrogen.}
\end{array}$$

Two atoms of ferrous sulphate, one atom of hydrated sulphuric acid, and one atom of hydrated nitric acid, produce three atoms of ferric sulphate, one atom of water, and one atom of peroxide of nitrogen.

I hope the reader will do justice to the explanations of these transformations, by examining the terms in which the facts are explained in the systems of chemistry based on the ordinary theory. In most cases, the peroxidation and protoxidation of iron salts are described about as clearly as the alchemists were wont to describe the transmutation of lead into gold.

Condition of Iron in double salts of Peroxide of Iron. Example: The oxalate of potash and of peroxide of iron. I copy the usual formula from *Graham's Chemistry:*—

$$3(KO,C_2O_3) + Fe_2O_3,3C_2O_3 + 6HO.$$

This formula indicates the following ultimate atoms, according to the proposed new equivalents, in which the atomic weights of carbon and oxygen are doubled:—

$$K^3Fec^3C^6O^{12} + 3H^2O.$$

Dividing these numbers by 3, we obtain K,Fec; C^2O^4+Aq, or KCO^2+$FecCO^2$+Aq. That is to say, the salt is a double oxalate of the simplest possible form, and in which the ferric atom Fec, is perfectly equivalent to the potassium atom K. There is absolutely no evidence to prove the presence of sesquioxide of iron in this salt; though the heaping together of six equivalents of oxalic acid, six equivalents of water, and three equivalents of potash, all take place in consequence of the assumption that sesquioxide of iron forms an essential and indivisible part of this compound. The salt, in fact, is made up after Berzelius's law, that when electro-negative oxides combine with electro-positive oxides, the oxygen of the former (in neutral compounds) is a multiple by a whole number of the oxygen in the latter. The adoption of double equivalents will render this law obsolete.

The greater part of the organic salts of peroxide of iron stand in exactly similar circumstances to this oxalate. They are made to contain 3 atoms of acid without the slightest necessity. In Gmelin's and in Gerhardt's Chemistry, there are scores of complicated formulæ that immediately are simplified if you adopt the ferric atom, and abandon the lumbering sesquioxide of iron, which, in fact, cannot be proved to exist in any salt whatever.

Finally, let us apply these views to the investigation of some of the cyanides that contain iron.

First of all, we must come to an understanding as to the meaning of the words *cyanide* and *cyanogen*. According to Mr. Gerhardt,[1] the composition of cyanogen is expressed by the formula $C^4N^4 = Cy^2Cy^2$. He tells us, that most chemists represent free cyanogen by the formula $C^2N^2 = 2$ volumes; but that, in his opinion, cyanogen is the cyanide of cyanogen, just as hydrocyanic acid is the cyanide of hydrogen:—

$$\text{Cyanide of hydrogen (4 volumes).} \quad \left.\begin{matrix} Cy^2 \\ H^2 \end{matrix}\right\} \qquad \text{Cyanide of cyanogen (4 volumes).} \quad \left.\begin{matrix} Cy^2 \\ Cy^2 \end{matrix}\right\}$$

That line of argument is beyond my comprehension. I understand the statement that cyanide of hydrogen contains cyanogen as an acid radical, combined with hydrogen as a basic radical; but I must inquire, if there is no such thing as free cyanogen, what can possibly be the constituents, either of the cyanide of hydrogen or the cyanide of cyanogen? Mr. Gerhardt's theory of free cyanogen, if extended to the elements, as some chemists seem desirous of extending it, leads to very singular conclusions. With vast propriety, we then declare that iron is not free iron, but the ferride of iron; that hydrogen is not free hydrogen, but the hydride of hydrogen; that oxygen is not free oxygen, but the oxide of oxygen. Proceeding in this manner, we get rid of all the elements, replacing each by a hypothetical compound of an imaginary + element, combined with an imaginary − element. Such are some of the fashionable whimsies of men of science.

My notion of free cyanogen is, that it consists of one atom of carbon combined with one atom of nitrogen; that it forms a compound which in the gaseous state measures one volume, weighs 26 on the hydrogen scale, and has the power to combine with one atom, or one volume, of any element or of any compound. That is a plain prosaic account of cyanogen. I denote it by CN or Cy. Hence,

HCy = Hydrocyanic acid.
KCy = Cyanide of potassium.

When I am told that this cyanogen, which I can make, and isolate, and test, and weigh, and measure, and cause to go into compounds and to come out of them, and to be again the same isolated cyanogen, with the same properties, the same weight, and the same measure; when I am told that I am to believe that this compound which I know is not free cyanogen, but that free cyanogen is cyanide of cyanogen, a compound of two other cyanogens, which I do not know, which I cannot make, and which nobody ever saw, then I begin to think that I am listening to a lecture on exoteric chemistry delivered by a philosopher of Ancient Egypt, whose intention it is that I shall acquire no knowledge of esoteric chemistry, and who has been constituted an authority under the conservative opinion that the proper use of a chemical theory is to enable a chemist to conceal his knowledge.

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[1] Traité de Chimie, I. 288.

Passing by this occult philosophy, let us proceed to examine the compounds of cyanogen.

I quote the following two formulæ from Gmelin's Chemistry:—

Protocyanide of iron, or ferrous cyanide $C^6N^3Fe^3 = Fe\,Cy$.
Sesquicyanide of iron, or ferric cyanide $C^6N^3Fe^2 = Fe^2Cy^3$.

According to the Radical Theory, these formulæ are transformed as follows:—

Ferrous cyanide $= Fe\,Cy$.
Ferric cyanide $= FecCy$.

These symbols are not only simple, but they show what the old symbols do not show, that the iron in the two salts is not only present in a different quantity, but in a different condition. There is no reason whatever why the ferric atom should not be divided in this manner. No fact forbids it. No experiment is opposed to it. The only argument that can be urged is, that it does not agree with Dalton's theory of combination in multiple proportions. That is unlucky. But I must reply, that if Dalton's theory is found to be inconsistent with truth, or comes to be a cause of perplexity, instead of a help, to chemists, they will have to consider whether that theory must not be amended or abandoned.

All the single cyanides can be expressed in the same manner as the above; even these containing compound radicals and organic radicals, such as—

$CH^3,\ Cy$ = Cyanide of methyl.
NH^3Pt, Cy = Ammonio-protocyanide of platinum.
AsC^2H^6, Cy = Cyanide of cacodyl.

The next three formulæ are quoted from Gmelin:—

Ferricyanide of potassium, or red prussiate of potash . .	$3KCy, Fe^2Cy^3 = C^6N^3K^3, C^6N^3Fe^2$.
Hydroferricyanic acid . . .	$3HCy, Fe^2Cy^3 = C^6N^3H^3, C^6N^3Fe^2$.
Turnbull's Prussian blue . .	$3FeCy, Fe^2Cy^3 = C^6N^3Fe^3, C^6N^3Fe^2$.

By adopting separate symbols for the ferrous and ferric atoms, both of which occur in Turnbull's Prussian blue, and then dividing everything in these formulæ by 3, we are enabled to simplify them thus:—

Ferricyanide of potassium . . .	$K\,Cy,FecCy$.
Hydroferricyanic acid	$H\,Cy,FecCy$.
Turnbull's Prussian blue. . . .	$FeCy,FecCy$.

Thus a series of compounds which require very complex formulæ, according to every theory hitherto produced, demand, upon the radical theory, formulæ of the simplest possible character. All the double cyanides that correspond with the red prussiate of potash have this very simple constitution. They are double cyanides, having one basylous atom and one basylic atom, and in all cases of double decomposition *the basylic atom accompanies the two atoms of cyanogen.* Among the basylic atoms which produce salts of this kind are Ag, Au, Cd, Coc, Crc, Cuc, Fec, Hg, Mnc, Ni, Pt, Zn. Any of these may have hydrogen as the basylous atom, producing acids corresponding to the hydroferricyanic acid.

These double cyanides may be strictly compared with the oxalates in their form and their mode of action:—

Red prussiate of potash . .	$KCy,FecCy = K,FecCy^2$.
Oxalate of potash	$KO,\ C\ \ O = K,C\ \ O^2$.

The following formulæ of triple cyanides are quoted from Gmelin:—

Ferrocyanide of potassium, or yellow prussiate of potash.	$K^2FeCy^3 = C^6N^3FeK^2$.
Hydroferrocyanic acid . . .	$H^2FeCy^3 = C^6N^3FeH^2$.
Common Prussian blue . .	$C^6N^3Fe^3,2C^6N^3Fe^2$ $= 3FeCy,2Fe^2Cy^3\ (xHO)$.[1]

The complexity of this last formula is ludicrous. The simple fact is, that the K^2 and H^2 of the two first salts is, in a case of double decomposition, exchanged for two ferric atoms = Fec^2; but the prevailing theory of the sesquioxides, enjoining the use of three times that quantity of iron, and presenting no other solution of the difficulty, the entire formula has to be enlarged to accommodate the theory. The above three salts would be written with the new equivalents as follows:—

Yellow prussiate of potash . . .	$K\ \ Cy,K\ \ Cy,FeCy = K^2\ FeCy^3$.
Hydroferrocyanic acid	$H\ \ Cy,H\ \ Cy,FeCy = H^2\ FeCy^3$.
Common Prussian blue	$FecCy,FecCy,FeCy = Fec^2FeCy^3$.

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[1] I omit the water, as of no moment in this inquiry.

Just as the last class of cyanides (the double cyanides) may be compared with the oxalates, so may this class of triple cyanides be compared with the carbonates :—

Yellow prussiate of potash . $KCy,KCy,FeCy = K^2FeCy^3$.
Carbonate of potash . . . . $KO,\ KO,\ C\ O = K^2C\ O^3$.

And in cases of double decomposition, just as the carbon and oxygen of the carbonate CO^3 go together, so do the ferrous atom and the cyanogen of the cyanide $FeCy^3$ go together.

Examples.—Formation of Prussian blue with yellow prussiate of potash and ferric sulphate :—

$$\begin{array}{l} \mathbf{KK},FeCy^3. \\ Fec,\mathbf{SO}^2. \\ Fec,\mathbf{SO}^2. \end{array}$$

Formation of Prussian blue with red prussiate of potash and ferrous sulphate :—

$$\begin{array}{l} \mathbf{K},FecCy^2. \\ Fe,\mathbf{SO}^2. \end{array}$$

The two varieties of Prussian blue are therefore,

$$\begin{array}{rcr} Fec,Fec;\ Fe\ Cy^3 & = & FecCy,FecCy,FeCy. \\ Fe,FecCy^2 & = & FecCy,FeCy. \end{array}$$

The action of chlorine, in converting yellow prussiate of potash into red prussiate of potash, is easy of explanation by means of the proposed equivalents :—

$$\left.\begin{array}{l} K^2\,\mathbf{Fe}\,Cy^3 \\ K^2\,\mathbf{Fe}\,Cy^3 \\ +\quad Cl \end{array}\right\} = \left\{\begin{array}{l} K\,\mathbf{Fec}\,Cy^2. \\ K\,\mathbf{Fec}\,Cy^2. \\ K\,\mathbf{Fec}\,Cy^2. \\ K\,Cl. \end{array}\right.$$

Namely, the chlorine converts 2 ferrous atoms into 3 ferric atoms; these, with 3 atoms of potassium and 6 atoms of cyanogen, produce 3 atoms of the double cyanide or red prussiate of potash. The superfluous 4th atom of potassium combines with an atom of chlorine to form chloride of potassium.

There is a class of fourfold cyanides, of which Prussian green may be taken as an example. Gmelin's formula of that compound is $C^6N^3Fe^3$, $3C^6N^3Fe^3 + 12HO = FeCy,Fe^2Cy^3 + 4HO$. This is another case where iron occurs in both conditions. The reduction of the formula gives—

$$FeFec^3Cy^4 + 2H^2O.$$

Finally, I must bestow a few words upon the question whether hydrocyanic acid is monobasic or polybasic.

a. If we take a quantity of hydrocyanic acid equal to HCy,[1] we can, by replacing H by a basic radical, produce a great variety of cyanides of this form, MCy.

The hydrocyanic acid is therefore MONOBASIC.

b. If we take a quantity of the acid equal to $\mathrm{HHCy^2}$, we can, by replacing HH, either singly or together, produce a great variety of acid or neutral salts, such as

$\mathrm{HFecCy^2}$ . . .	Hydroferricyanic acid.
$\mathrm{KFecCy^2}$ . . .	Red prussiate of potash.
$\mathrm{HCrcCy^2}$ . . .	Hydrochromidcyanic acid.
$\mathrm{HAgCy^2}$ . . .	Argentoprussic acid.
$\mathrm{KAgCy^2}$ . . .	Argentocyanide of potassium.

The hydrocyanic acid is therefore BIBASIC.

c. If we take a quantity of the acid equal to $\mathrm{HHHCy^3}$, and replace HHH partly or entirely with basic radicals, we can produce such salts as

$\mathrm{HHFeCy^3}$ . . .	Hydroferrocyanic acid.
$\mathrm{KKFeCy^3}$ . . .	Yellow prussiate of potash.
$\mathrm{C^2H^5,C^2H^5;FeCy^3}$ . . .	Ferrocyanide of ethyl.
$\mathrm{ZnZnBaCy^3}$ . . .	Cyanide of zinc and barium.

The hydrocyanic acid is therefore TRIBASIC.

d. If we take a quantity of the acid equal to $\mathrm{HHHHCy^4}$, and replace HHHH by basic radicals, we produce such salts as

$\mathrm{Fe, Fec, Fec, Fec;\ Cy^4}$ . . .	Prussian green.
$\mathrm{K, Na, Fec, Fec;\ Cy^4}$ . . .	Cyanide of potassium, sodium, and ferricum.
$\mathrm{Cu, Ag, Ag, Ag;\ Cy^4}$ . . .	Cuprocyanide of silver.
$\mathrm{K, Auc, Auc, Auc;\ Cy^4}$ . . .	Auridcyanide of potassium.

The hydrocyanic acid is therefore TETRABASIC.

It appears to be probable that the nitro-prussides discovered by Dr. Lyon Playfair contain octabasic cyanides.

Pray tell me, then, is hydrocyanic acid monobasic, bibasic, tribasic, tetrabasic, or octabasic?

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[1] $\mathrm{H} = 1$, $\mathrm{C} = 12$, $\mathrm{N} = 14$. $\mathrm{HCy} = 27$.

The cyanides of iron, of all classes, single, double, triple, and quadruple, contain iron in its two chemical conditions, and in such proportions as seem not only to justify the assumption of the existence of the ferrous and ferric atoms, but to render the prevalent hypothesis of the *indivisibility* of that quantity of iron which corresponds to the *sesquioxide* altogether improbable and untenable. I have shown that we can have complete salts with one atom of Fec, with two atoms, and with three atoms. The resolution adopted by chemists of making it appear that all the "persalts" of iron contain three atoms of Fec, is at variance with the plainest, straightforward method of representing the facts as they stand out clearly in our view. It serves only to sustain the credit of an unnecessary and extravagant hypothesis. The time will come when chemists will hold the doctrine of the sesquioxides in the same respect as they now hold the doctrine of phlogiston, which is its exact parallel in common sense and practical utility.

The limits of this essay forbid an extension of these illustrations, either in relation to iron or to the equivalents of other elements. Besides, they will occur in abundance to any reflecting chemist who turns his attention to this subject.

Examples of Compound Organic Radicals and the Salts that contain them.

C.	H.	Radicals.	Salts.	
1	1	Formyl	H,CHO^2.	Formic Acid.
			CH,CHO	Pyrogallic Acid.
			Pb,CHO	Pyrogallate of Lead.
1	2	Vinyl	CH^2	[Olefiant Gas.]
1	3	Methyl	CH^3,CH^3O	Methylic Ether.
			H,CH^3	Marsh Gas.
			CH^3,SO^2.	Methylic Sulphate.
2	1		$H,C^2H\ O^2$	Aconitic Acid.
2	1		$H,C^2H\ O^2$	Fumaric Acid.
2	1		$H,C^2H\ O^2$	Maleic Acid.
2	2		$H,C^2H^2O^2$	Succinic Acid.
2	2		$H,C^2H^2O^3$	Tartaric Acid.
2	3	Acetyl	H,C^2H^3O	Aldehyde.
			$H,C^2H^3O^2$	Acetic Acid.
2	3		$H,C^2H^3O^3$	Homolactic Acid.
2	3		$H,C^2H^3O^3$	Glycollic Acid.
2	5	Ethyl	H,C^2H^5O	Alcohol.
			C^2H^5,C^2H^5O	Ether.
3	3	Acryl?	H,C^3H^3O	Acroleine.
			$H,C^3H^3O^2$	Acrylic Acid.
3	3		$H,C^3H^3O^3$	Pyruvic Acid.
3	3	Pteleyl	C^3H^3,NO^2	Nitrite of Pteleyl.
3	4		$H,C^3H^4O^4$	Mucic Acid.
3	4		$H,C^3H^4O^2$	Adipic Acid.
			$C^2H^5,C^3H^4O^2$	Adipate of Ethyl.
3	5	Acryl?	H,C^3H^5O	Acrylic Alcohol.
3	5	Allyl	C^3H^5,C^3H^5O	Oxide of Allyl.
3	5	Propionyl	H,C^3H^5O	Propionic Aldide.
			H,C^3H^5	Propylene.
			$H,C^3H^5O^2$	Propionic Acid, hydrate.
			$C^3H^5,C^3H^5O^3$	Propionic Acid, anhydr.
3	5		$H,C^3H^5O^3$	Lactic Acid.
3	5		$H,C^3H^5O^2$	Metacetonic Acid.
3	7	Propyl	$C^3H^7,C^3H^5O^2$	Propylal.
			H,C^3H^7O	Propylic Alcohol.
			C^3H^7,NH^2	Propylamine.
3	7	Lipyl	$H,C^3H^7O^3$	Glycerine.
4	2		$H,C^4H^2O^2$	Phtalic Acid.

C.	H.	Radicals.	Salts.	
4	2		$H^4,C^4H^2O^6$	Tartaric Acid.
4	2		$H^2,C^4H^2O^5$?	Tartrelic Acid.
4	3		$H, C^4H^3O^5$?	Tartrelic Acid.
4	4		$H^2,C^4H^4O^6$	Metatartaric Acid.
4	4		$H^2,C^4H^4O^5$	Malic Acid.
			$Ag^2,C^4H^4O^5$	Malate of Silver.
4	6	Suberyl	$H,C^4H^6O^2$	Suberic Acid.
4	7	Butyryl	H,C^4H^7O	Butyral.
			$H,C^4H^7O^2$	Butyric Acid.
4	9	Butyl	H,C^4H^9O	Butylic Alcohol.
		(Valyl)	C^4H^9,NO^2	Nitrite of Butyl.
5	3		$H,C^5H^3O^2$	Furfurol.
5	3		$H,C^5H^3O^3$	Pyromeconic Acid.
5	3		$H,C^5H^3O^3$	Pyromucic Acid.
5	4		$H^2,C^5H^4O^4$	Citraconic Acid.
5	4	Naphthaline	C^5H^4,Cl	Chloride of Naphthaline.
5	6		$H^2,C^5H^6O^4$	Pyrotartaric Acid.
5	7	Angelyl	$H,C^5H^7O^2$	Angelic Acid.
5	7	Camphoryl.	$H,C^5H^7O^2$	Camphoric Acid.
			C^5H^9,C^5H^7O	Camphor.
			C^5H^9,C^5H^7	Turpentine.
5	8		$H,C^5H^8O^2$	Sebacic Acid.
5	9	Valeryl.	H,C^5H^9O	Valeral.
			$H,C^5H^9O^2$	Valerianic Acid.
5	11	Amyl	$H,C^5H^{11}O$	Amylic Alcohol.
6	2		$H^2,C^6H^2O^5$?.	Comenic Acid.
6	3		$H,C^6H^3O^5$?.	
6	5		$H^3,C^6H^5O^7$	Citric Acid.
6	5	Phenyl.	H,C^6H^5O	Phenole (Phenic Acid).
			H,C^6H^5	Benzine.
			$H,C^6H^5;S^2O^4$	Phenyl-Sulphuric Acid.
6	11		$H,C^6H^{11}O^6$	Glucic Acid.
6	11	Caproyl	$H,C^6H^{11}O^2$	Caproic Acid.
			$H,C^6H^{11}O$	Capral.
6	13	Hexyl	$H,C^6H^{13}O$	Caproic Alcohol.
7	1		H^3,C^7HO^7	Meconic Acid.
7	3		$H^3,C^7H^3O^5$?	Gallic Acid.
7	4		$H^2,C^7H^4O^5$?	
7	5	Salicyl.	$H,C^7H^5O^2$?.	Salicylous Acid.
			$H,C^7H^5O^3$?.	Salicylic Acid.
			$H,C^7H^5O^4$?.	Salicylic Acid. ?

C.	H.	Radicals.	Salts.	
7	5	Benzyl	H,C^7H^5O	Oil of Bitter Almonds.
			$H,C^7H^5O^2$	Benzoic Acid.
			C^7H^5,ClO	Chloride of Benzoyl.
7	7	Toluenyl	H,C^7H^7	Toluine.
			C^7H^7,Cl	Chloride of Toluenyl.
			C^7H^7,NO^2	Nitrotoluine.
7	9		$H^3,C^7H^9O^6$	Quinic Acid.
7	10		$H^2,C^7H^{10}O^4$	Pimelic Acid.
7	13	Œnanthyl	$H,C^7H^{13}O$	Œnanthol.
			$H,C^7H^{13}O^2$	Œnanthylic Acid.
7	15	Heptyl?	$H,C^7H^{15}O$	Castor-oil Alcohol.
			$C^4H^5,C^7H^{15}O$	Ethyl-œnanthyl Ether.
			$C^7H^{15},C^8H^{15}O$?	Caprylone.
8	7	Toluyl	$H,C^8H^7O^2$	Toluic Acid.
8	7	Anisyl	$H,C^8H^7O^3$	Anisic Acid.
			C^8H^7,ClO^2	Chloride of Anisyl.
8	15	Capryl	$H,C^8H^{15}O^2$	Caprylic Acid.
			$H,C^8H^{15}O$	Caprylic Aldehyde.
			H,C^8H^{15}	Caprylene.
8	17	Octyl	$H,C^8H^{17}O$	Caprylic Alcohol.
			$C^8H^{17},C^4H^3O^2$	Acetate of Octyl.
			$H,C^8H^{17}; S^2O^4$	Sulphocaprylic Acid.
9	7	Cinnamyl	$H,C^9H^7O^2$	Hydride of Cinnamyl.
			$H,C^9H^7O^3$	Cinnamic Acid.
			C^9H^7,ClO	Chloride of Cinnamyl.
9	9	Styryl	$C^9H^9,C^9H^7O^2$	Cinnamate of Styryl.
			H,C^9H^9O	Styrone.
9	9		$H,C^9H^9O^2$	Xylitic Acid.
9	11	Mesityl.	H,C^9H^{11}	Mesitylol.
9	11	Cumenyl	H,C^9H^{11}	Cumene.
			$H,C^9H^{11}; S^2O^3$	Cumenyl-Sulphurous Acid.
9	17	Pelargyl	$H,C^9H^{17}O^2$	Pelargonic Acid.
10	11	Cumyl	$H,C^{10}H^{11}O^2$	Cuminic Acid.
			$H,C^{10}H^{11}O$	Hydrate of Cumyl.
			$K,C^{10}H^{11}O$	Cumilide of Potassium.
10	11		$H,C^{10}H^{11}O$	Essence of Anis.
10	13	Thymyl	$H,C^{10}H^{13}O$	Hydrate of Thymyl.
			$H,C^{10}H^{13}; S^2O^4$	Thymyl-Sulphuric Acid.
10	17	Camphyl	$H,C^{10}H^{17}O^2$	Campholic Acid.
10	19	Rutyl	$H,C^{10}H^{19}O^2$	Rutic Acid.

C.	H.	Radicals.	Salts.	
10	19	Rutyl	$Am,C^{10}H^{19}; S^2 O^3 + 2Aq$	Sulphite of Rutyl-Ammonium.
10	19		$H,C^{10}H^{19}O^2$	Capric Acid.
11	21		$H,C^{11}H^{21}O^2$	Margaritic Acid.
12	23	Lauryl	$H,C^{12}H^{23}O^2$	Lauric Acid.
13	25	Cocinyl	$H,C^{13}H^{25}O^2$	Cocinic Acid.
14	27	Myristyl	$H,C^{14}H^{27}O^2$	Myristic Acid.
15	29		$H,C^{15}H^{29}O^2$	Benic Acid.
15	31		$C^{15}H^{31},C^{16}H^{31}O$	Palmitone.
16	31	Palmityl	$H,C^{16}H^{31}O^2$	Palmitic Acid.
			$H,C^{16}H^{31}$	Cetene.
			$C^5H^{11},C^{16}H^{31}O^2$	Palmitate of Amyl.
16	33	Cetyl	$H,C^{16}H^{33}O$	Ethal.
			$H,C^{16}H^{33}; S^2O^4$	Cetyl-Sulphuric Acid.
17	33		$H,C^{17}H^{33}O^2$	Margaric Acid.
			$C^2H^5,C^{17}H^{33}O^2$	Margarate of Ethyl.
18	33		$H,C^{18}H^{33}O^2$	Oleic Acid.
18	33		$H,C^{18}H^{33}O^3$	Ricinolic Acid.
18	35		$H,C^{18}H^{35}O^2$	Stearic Acid.
			$C^5H^{11},C^{18}H^{35}O^2$	Stearate of Amyl.
19	37		$H,C^{19}H^{37}O^2$	Balenic Acid.
20	39		$H,C^{20}H^{39}O^2$	Butynic Acid.
21	41		$H,C^{21}H^{41}O^2$	Behenic Acid.
27	53		$H,C^{27}H^{53}O^2$	Cerotic Acid.
27	55	Ceryl	$H,C^{27}H^{55}O$	Hydrate of Ceryl.
30	59	Melissyl	$H,C^{30}H^{59}O^2$	Melissic Acid.
30	61	Myricyl.	$H,C^{30}H^{61}O$	Hydrate of Myricyl.
			$C^{30}H^{61},C^{16}H^{31}O^2$	Palmitate of Myricyl.

Compound Organic Radicals.

The compound radicals contained in this Table are compounds of carbon and hydrogen only. They are free from oxygen, nitrogen, chlorine, and sulphur. They vary greatly in composition, from Formyl = CH to Myricyl = $C^{30}H^{61}$.

To some of these radicals I have applied the names by which they are commonly known; to others the names that are sometimes applied to what I should call their oxides; while many of them are still without names. To assist in their identification, I have cited a variety of salts that are commonly assumed to contain them. The formulæ of these salts are written according to the plan advocated in this paper, and to be explained in a subsequent section.

A difficulty in applying names to these radicals arises from the fact, that the same combination of carbon and hydrogen apparently acts as a radical in salts of very different character. Thus, the compound C^3H^5 seems to represent acryl, allyl, propionyl, and the radicals of the lactic and metacetonic acids. So also C^6H^5 represents phenyl and the radical of the citric acid. Whether in such cases we have to do with one radical or with more than one, it is at present impossible to determine. It is not unlikely that some of these are synonymous terms for the same thing, and may hereafter be dispensed with.

I accept these radicals, theoretically, as the chemical equivalents of atoms of the elements. Whatever may be the complexity of the constitution of a radical—whatever the number of its atoms of carbon and hydrogen—I consider that it forms one molecule; that its chemical action is that of one atom or one equivalent; that when it acts as an acid radical, it replaces one volume of chlorine or combines with one volume of hydrogen; that when it is a basic radical, it combines with one volume of chlorine, or replaces one volume of hydrogen. A compound radical is in all respects the chemical equivalent of one atom, or one volume, of any element, except oxygen.

The assumption of the existence of these radicals is purely theoretical. The evidence in support of the assumption is to be given in the following pages.

Let me repeat, that I speak of radicals that contain carbon and hydrogen only. Compounds that contain oxygen or nitrogen are of a totally different character.

The materials for this table have been principally derived from GMELIN's *Handbook of Chemistry* and GERHARDT's *Traité de Chimie Organique*. The table is not to be considered as presenting anything more than a selection of examples to illustrate what I mean by compound radicals and their combinations. Those who desire more detailed information may consult the two systematic works that I have just named.

Composition, Specific Gravities, Atomic Weights, and Atomic Measures of Gases and Vapours.

The compounds named in this Table exceed three hundred. They are arranged alphabetically, according to the names in common use. They have formulæ according to the system described in this Essay. The following particulars are given of each compound:—

1. The observed specific gravity of the gas, stated against that of atmospheric air taken as unity; with the name of the observer.
2. The observed specific gravity stated against the specific gravity of hydrogen gas taken as unity.
3. The atomic weight of each compound on the hydrogen scale.
4. The theoretical specific gravity on the same scale.
5. Under the head of atomic measure I have given the number of volumes which contain an atom, or equivalent, of each gas.

In connection with the proposal to mark the specific gravities of gases in numbers relating to their atomic weights, I take this opportunity of suggesting, that the vessels in which chemists are accustomed to measure gases, might be graduated in such a manner as to indicate the weight of the gases. This can be effected by adopting, as a standard gas measure, a vessel that contains one grain of hydrogen gas, the volume of which at 60° F., and 30 ins. Bar., is 46·7 cubic inches. This vessel may be divided into 100 spaces, each of which will contain $\frac{1}{100}$ grain of hydrogen gas. A vessel, one-tenth of that size, = $4\frac{2}{3}$ cubic inches, divided into 100, would have divisions, each = $\frac{1}{1000}$ grain of hydrogen gas. The weight of any gas measured in these vessels would be found by multiplying the measure of the gas by its specific gravity, according to the theoretical number given in the following Table. Thus, 80 measures of dry nitrogen gas collected in the small tube, at 30 ins. Bar. and 60° F., would weigh $0·080 \times 14 = 1·12$ grain. Of course, corrections upon the measure of a gas, collected over water at another temperature, and under a different pressure, would have to be made as usual. Vessels thus graduated would be useful for class experiments, as well as for analytical purposes. To give one example,—A receiver for showing the combustion of phosphorus in oxygen gas, may be known to contain 10 grains of hydrogen gas. The question is, how much chlorate of potash will afford oxygen gas sufficient to fill it. 10 grains of H = 10 atoms of H = 10 atoms of O. The formula of chlorate of potash being $KClO^3$, the quantity required is $3\frac{1}{3}$ atoms, and taking the atom of this salt at 122·5 grains, we find that $122\frac{1}{2} \times 3\frac{1}{3} = 408\frac{1}{3}$ grains of the chlorate of potash will give the requisite quantity of oxygen gas.

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Atmospheric Air				14.47	14.47	1.00[illegible]	
Acetic Acid, Hydrate	$H,C^2H^3O^2$	60.	2	30.	30.1	2.[illegible]	Cahours.
— Anhydrous	$C^2H^3,C^2H^3O^3$	102.	2	51.	50.21	3.47	Gerhardt.
Acetone	CH^3,C^2H^3O	58.	2	29.	29.26	2.022	Dumas.
Acetylamine	$NH,C^2H^3;H$	43.	2	21.5	22.02	1.522	Natanson.
Acetyl, Bromide	$C^2H^3,Br.$	107.	2	53.5	53.41	3.691	Regnault.
— Chloride	$C^2H^3,Cl.$	62.5	2	31.25	30.62	2.116	Regnault.
— Iodide	C^2H^3,I	154.	2	77.	69.17	4.78	Regnault.
— Oxychloride	C^2H^3,ClO	78.5	2	39.25	41.53	2.87	Gerhardt.
— Hydrate (Aldehyd)	H,C^2H^3O	44.	2	22.	22.17	1.532	Liebig.
Acryl	C^3H^5	41.	1	41.	42.25	2.92	Berthelot.
Acrylic Alcohol	H,C^3H^5O	58.	2	29.	29.21	2.019	Dumas.
Acroleine	H,C^3H^3O	56.	2	28.	27.45	1.897	Redtenbacher.
Allyl, Sulphocyanide	$C^3H^5,Cy;S^2$	99.	2	49.5	49.2	3.4	Dumas.
Ammonia	$NH^3 = H,NH^2$	17.	2	8.5	8.63	0.5967	Biot and Arago.
— Carbamate	$NH^4,NH^2;CO^2?$	78.	6	13.	13.01	0.8992	Rose.
— Hydrochlorate	H,NH^2+HCl	53.5	4	13.375	12.88	0.89	Bineau.
— Hydrocyanate	H,NH^2+HCy	44.	4	11.	11.61	0.8021	Bineau.
— Hydrosulphate, Acid	$H,NH^2+(HS)^2$	51.	4	12.75	13.039	0.9011	Bineau.
— — Neutral	H,NH^2+HS	34.	3	11.33	11.356	0.7848	Bineau.
— Hydrotellurate	H,NH^2+HTe	82.	4	20.5	19.1	1.32	Bineau.
Amyl	C^5H^{11}	71.	1	71.	70.89	4.899	Frankland.
— Hydride	H,C^5H^{11}	72.	2	36.	35.93	2.483	Frankland.

Name of Gas.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Amylic Alcohol	$H,C^5H^{11}O$	88.	2	44.	45.54	3.147	Dumas.
Amyl, Borate C_5H_{11} BO }O	C^5H^{11},BO	90.6	$\frac{4}{6}$	135.9	152.66	10.55	Ebelmen.
— Chloride	C^5H^{11},Cl	106.5	2	53.25	54.99	3.8	Balard.
— Cyanide	C^5H^{11},Cy	97.	2	48.5	48.26	3.335	Frankland.
— Iodide	C^5H^{11},I	198.	2	99.	96.59	6.675	Cahours.
— Acetate	$C^5H^{11},C^2H^3O^2$	130.	2	65.	64.51	4.458	Cahours.
— Nitrite C_5H_{11} NO }O	C^5H^{11},NO^2	117.	2	58.5	58.31	4.03	Balard.
— Oxalate $2C_5H_{11}, C_2O_4$	C^5H^{11},CO^2	115.	1	115.	121.55	8.4	Balard.
— Silicate $4C_5H_{11}, SiO_4$	C^5H^{11},SiO	94.5	$\frac{1}{2}$	189.	169.3	11.7	Ebelmen.
— Sulphide $2C_5H_{11}, S$	C^5H^{11},S	87.	1	87.	91.16	6.3	Balard.
— Hydrosulphide	$C^5H^{11},H; S^2$	104.	2	52.	52.54	3.631	Krutzsch.
— Valerianate	$C^5H^{11},C^5H^9O^2$	172.	2	86.	89.28	6.17	Balard.
— — Peppermint Camphor	C^5H^{11},C^5H^9O	156.	2	78.	81.32	5.62	Walter.
Anilin	$NH,C^6H^5; H$	93.	2	46.5	46.58	3.219	Barral.
Anis, Essence of	$H,C^{10}H^{11}O$	148.	2	74.	75.1	5.19	Cahours.
Angelyl, Hydrate (Guajacene)	H,C^5H^7O	84.	2	42.	42.25	2.92	Deville.
Antimony, Terchloride	SbcCl	78.5	$\frac{4}{6}$	117.75	112.87	7.8	Mitscherlich. 8·1
Antimoniuretted Hydrogen	SbcH	44.	$\frac{4}{6}$	66.	66.01	4.562	Rose.
Arsenic	As or Asc^3	75.	$\frac{3}{6}$	150.	150.01	10.367	Bunsen. 16
—	Asc	25.	$\frac{1}{6}$	150.	150.01	10.3[illegible]	Bunsen.
— White Oxide	Asc^2O^3	198 ~~66.~~	1 $\frac{2}{6}$	198.	200.41	13.85	Mitscherlich.
— Chloride	AscCl	60.5	$\frac{4}{6}$	90.75	91.17	6.3006	Dumas.
— Iodide	AscI	152.	$\frac{4}{6}$	228.	232.97	16.1	Mitscherlich.
Arseniuretted Hydrogen	AscH	26.	$\frac{4}{6}$	39.	39.	2.695	Dumas.

1.706

3.4

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Arsentriethyl	AsC^2H^5	54.	$\frac{4}{6}$	81.	76.37	5.2783	Landolt.
Benzoile, Chlorohydride	$H,C^7H^5;Cl^2$	161.	2	80.5	80.96	5.595	Cahours.
Benzoic Acid, Cryst.	$H,C^7H^5O^2$	122.	2	61.	61.79	4.27	Dumas.
Benzoile, Chloride	C^7H^5,ClO	140.5	2	70.25	72.16	4.987	Cahours.
Bismuth, Chloride	BicCl	106.5	$\frac{4}{6}$	159.75	161.49	11.16	Jacquelain.
Boron, Chloride	BCl 78.2	39.1	$\frac{4}{6}$	58.6	57.04	3.942	Dumas.
— Fluoride	BF 45.2	22.6	$\frac{4}{6}$	33.9	33.46	2.3124	Dumas.
Bromine	Br	80.	1	80.	80.16	5.54	Mitscherlich.
Bromhydric Acid	HBr	81.	2	40.5	39.52	2.731	Liebig?
Butyl-Amyl	C^4H^9,C^5H^{11}	128.	2	64.	64.61	4.465	Wurtz.
Butyl-Hexyl	C^4H^9,C^6H^{13}	142.	2	71.	71.15	4.917	Wurtz.
Butyl	C^4H^9	57.	1	57.	58.65	4.053	Kolbe.
— Acetate	$C^4H^9,C^2H^3O^2$	116.	2	58.	58.94	4.073	Wurtz.
— Butylic Alcohol	H,C^4H^9O	74.	2	37.	37.46	2.589	Wurtz.
— Hydride	H,C^4H^9	58.	2	29.			
— Bromide	C^4H^9,Br	137.	2	68.5	68.3	4.72	Wurtz.
— Chloride	C^4H^9,Cl	92.5	2	46.25			
— Iodide	C^4H^9,I	184.	2	92.	89.96	6.217	Wurtz.
— Cyanide (Valeronitrile)	C^4H^9,CN	83.	2	41.5	41.85	2.892	Guckelberger.
Butylic Mercaptan	$H,C^4H^9;S^2$	90.	2	45.	44.86	3.1	Hermann.
Butylene Chloride	C^4H^8Cl,Cl	127.	2	63.5	64.04	4.426	Kolbe.
Butyrine, or Butylene	H,C^4H^7	56.	2	28.	28.84	1.993	Kolbe.
Butyral	H,C^4H^7O	72.	2	36.	37.77	2.61	Chancel.
Butyric Acid, hydrate	$H,C^4H^7O^2$	88.	2	44.	47.75	3.3	Pelouze and Gelis.

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Butyric Acid, Anhydrous	$C^4H^7,C^4H^7O^3$	158.	2	79.	77.85	5.38	Gerhardt.
Butyrone	C^3H^7,C^4H^7O	114.	2	57.	57.74	3.99	Chancel.
Cacodyl Model of Amidogen	AsC^2H^6	105.	1	105.	102.75	7.101	Bunsen.
— Oxide (Alkarsin)	$(AsC^2H^6)^2O$	226.	2	113.	109.32	7.555	Bunsen.
— Chloride	AsC^2H^6,Cl	140.5	2	70.25	65.98	4.56	Bunsen.
— Cyanide	AsC^2H^6,Cy	131.	2	65.5	67.	4.63	Bunsen.
— Sulphide	AsC^2H^6,S	121.	1	121.	111.71	7.72	Bunsen. 7.81
× — Oxychloride	$\left\{\begin{array}{l}6(AsC^2H^6,Cl)\\+(AsC^2H^6)^2O\end{array}\right\}$	1069.	14	76.36	79.	5.46	Bunsen.
Camphogene	C^5H^7	67.	1	67.	69.17	4.78	Delalande.
Campholene	$\left\{\begin{array}{l}C^4H^9,C^5H^7 \text{ or}\\C^5H^9,C^4H^7\end{array}\right\}$	124.	2	62.	62.99	4.353	Delalande.
Campholic Acid	$H,C^{10}H^{17}O^2$	170.	2	85.	87.66	6.058	Delalande.
Camphor	C^5H^9,C^5H^7O	152.	2	76.	76.94	5.317	Dumas.
Caprylene	H,C^8H^{15}	112.	2	56.	55.85	3.86	Bouis.
Caproic Alcohol	$H,C^6H^{13}O$	102.	2	51.	51.08	3.53	Faget.
Caproic Acid	$H,C^6H^{11}O^2$	116.	2	58.	61.64	4.26	Fehling.
Caprylic Alcohol	$H,C^8H^{17}O$	130.	2	65.	65.11	4.5	Bouis.
Carbonic Oxide	CO	28.	2	14.	14.	.96779	V. Wrede.
— Acid	CO^2	44.	2	22.	22.13	1.52908	Regnault.
Carbon, Sulphide (Xanthyl)	CS^4	76.	2	38.	38.27	2.6447	Gay-Lussac.
Castor-Oil Alcohol	$H,C^7H^{15}O$	116.	2	58.	58.14	4.018	Railton.
Cedrene	C^8H^{12}	108.	1	108.	114.31	7.9	Walter.
Cedrole	$C^8H^{14},C^8H^{12}O$?	234.	2	117.	121.55	8.4	Walter.

× Cadmium at 1040° 3.94 Deville & Troost 3.74 (56.03) 57.02

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Cetene	$H,C^{16}H^{31}$	224.	2	112.	115.86	8.007	Dumas and Peligot.
Chlorine	Cl	35.5	1	35.5	35.74	2.47	Gay-Lussac.
— Chloric Oxide	ClO^2	67.5	2	33.75			
— Hypochlorous Acid	Cl,ClO	87.	2	43.5	43.08	2.977	Millon ?
— Chlorous Acid	Cl,ClO^3	119.	3 ?	39.67	38.29	2.646	Millon.
— Chlorhydric Acid	HCl	36.5	2	18.25	18.05	1.2474	Biot and Arago.
CHLORINE COMPOUNDS.							
Chloride of Formyl	CH,Cl	48.5	1	48.5	48.05	3.321	Regnault.
Vinyl, containing Cl^1 ?	C(HCl)						
Protochloride of Carbon	CCl^2	83.	1	83.	84.22	5.82	Faraday.
Ethelene, Bibromide	$C^2H^4Br^2$	188.	2	94.	93.84	6.485	Regnault.
Vinyl, Bromide	CH^2Br	94.	1	94.			
Oil of Olefiant Gas, Dutch Liquid	CH^2,Cl	49.5	1	49.5	50.33	3.478	Regnault.
Methyl, containing Cl^1 ?	$C(H^2Cl)$						
Perchloride of Formyl	CH,Cl^2	84.	1	84.	83.45	5.767	Regnault.
Methyl, containing Cl^2 ?	$C(HCl^2)$						
Sesquichloride of Carbon	CCl^3 ?	118.5	1	118.5	118.03	8.157	Regnault.
Methyl, containing Cl^3 ?							
Chloroform	H,CCl^3	119.5	2	59.75	60.76	4.199	Dumas.
Chloride of Methyl	CH^3,Cl	50.5	2	25.25	25.12	1.736	Bunsen.
Bichloride of Carbon	CCl^3,Cl	154.	2	77.	77.13	5.33	Regnault.
Terchlorinated Methylic Sulphide	CCl^3,S	134.5	?		82.19	5.68	Riche.

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
C_2Cl_2O Monochlorinated Methylic Ether	CH^2Cl,CH^2ClO	115.	2	57.5	56.55	3.908	Regnault.
C_2Cl_4O Bichlorinated Ditto	$CHCl^2,CHCl^2O$	184.	2	92.	92.13	6.367	Regnault.
C_2Cl_6O Terchlorinated Ditto	CCl^3,CCl^3O	253.	4?	63.25	67.57	4.67	Regnault.
CCl_2 Bichloride of Methylene	CH^2Cl,Cl	85.	2	42.5	43.58	3.012	Regnault.
Hydride of Bichlorinated Methyl	$H,CHCl^2$						
Phosgene Gas	CCl,ClO	99.	2	49.5	50.07	3.4604	Thomson.
Chloraldehyd	C^2Cl^3,ClO	182.	2	91.	91.45	6.32	Malaguti.
Acetyl, Oxychloride.	C^2H^3,ClO	78.5	2	39.25	41.53	2.87	Gerhardt.
Chloracetic Acid	$H,C^2Cl^3O^2$	163.5	2	81.75	76.69	5.3	Dumas.
Chloral	H,C^2Cl^3O	147.5	2	73.75	74.23	5.13	Dumas.
Chloral, Hydrate	$H^3,C^2Cl^3O^2$	165.5	4	41.375	39.94	2.76	Dumas.
Acetyl, Chloride	C^2H^3,Cl	62.5	2	31.25	30.62	2.116	Regnault.
Ethyl, Chlorocarbonate Chlorovinic Formiate	$C^2H^5,CClO^2$	108.5	2	54.25	55.32	3.823	Dumas.
Perchlorovinic Formiate	$C^2Cl^5,CClO^2$	281.	2	140.5	134.72	9.31	Cloez.
Butylene Chloride Ethyl, containing Cl¹?	$C^2(H^4Cl)$	63.5	1	63.5	64.04	4.426	Kolbe.
Monochlorinated Vinic Ether	$(C^2H^4Cl)^2O$	143.	2	71.5	71.34	4.93	F. D'Arcet.
Ethyl, Chloride	C^2H^5,Cl	64.5	2	32.25	32.11	2.219	Thenard.
Monochlorinated Hydrochloric Ether	C^2H^4Cl,Cl	99.	2	49.5	50.33	3.478	Regnault.
Bichlorinated Hydrochloric Ether	$C^2H^3Cl^2,Cl$	133.5	2	66.75	65.55	4.53	Regnault.
Terchlorinated Ditto	$C^2H^2Cl^3,Cl$	168.	2	84.	83.91	5.799	Regnault.
Quadrichlorinated Ditto	$C^2H\ Cl^4,Cl$	202.5	2	101.25	100.93	6.975	Regnault.

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Hydrochlorate of Chloretherose	H,C^2Cl^5	202.5	2	101.25	102.53	7.087	Pierre.
Sesquichloride of Carbon	C^2Cl^5,Cl ?	237.	2	118.5	118.03	8.157	Regnault.
Acetyl, Perchloride	C^2H^3,Cl^3	133.5	2	66.75	68.	4.7	Regnault.
Hydride of Terchlorinated Ethyl	$H,C^2(H^2Cl^3)$?						
Chlorbenzid	$H,C^6H^2Cl^3$	181.5	2	90.75	92.18	6.37	Mitscherlich.
Chloro-Nitrous Gas	$ClNO$	65.5	2	32.75			
Chromium, Oxychloride	$ClCrO$	78.5	1	78.5	79.59	5.5	Dumas.
Chlorosulphuric Acid	$ClSO$	67.5	1	67.5	67.5	4.665	Regnault.
Sulphite of Perchloride of Carbon	$CCl^3SO + ClSO$	218.	2	109.	107.5	7.43	Kolbe.
Cumenyl, Hydride	H,C^9H^{11}	120.	2	60.	57·3	3.96	Gerhardt & Cahours.
Retinyl	H,C^9H^{11} ?	120.	2	60.	61.41	4.244	Walter.
Retinole	C^9H^{11},C^7H^5 ?	208.	2	104.	102.88	7.11	Walter.
Cumyl, Hydrate	$H,C^{10}H^{11}O$	148.	2	74.	75.82	5.24	Gerhardt.
Cyanogen	$CN = Cy$	26.	1	26.	26.14	1.8064	Gay-Lussac.
— Bromide	$CN,Br = CyBr$	106.	2	53.	52.19	3.607	Bineau.
— Chloride	$CN,Cl = CyCl$	61.5	2	30.75	30.55	2.111	Gay-Lussac.
— Solid Chloride (of Cyanyl)	Cy^3Cl	61.5	$\frac{2}{3}$	92.25	91.88	6.35	Bineau.
Cyanhydric Acid	$H,CN = HCy$	27.	2	13.5	13.71	·9476	Gay-Lussac.
Ethyl	C^2H^5	29.	1	29.	29.	2.004	Frankland.
— Ether	C^2H^5,C^2H^5O	74.	2	37.	37.42	2.586	Gay-Lussac.
— Alcohol	H,C^2H^5O	46.	2	23.	23.34	1.6133	Gay-Lussac.

C_4O_2
C_9O_2
C_6O_2

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Ethyl Acetate	$C^2H^5,C^2H^3O^2$	88.	2	44.	44.28	3.06	Dumas and Boullay.
— Benzoate	$C^2H^5,C^7H^5O^2$	150.	2	75.	78.22	5.406	Dumas and Boullay.
— Borate $3 C_2H_5, BO_3$	C^2H^5,BO	48.6	$\frac{4}{6}$	72.9	74.38	5.14	Ebelmen. 5·31
— Bromide	C^2H^5,Br	109.	2	54.5	54.32	3.754	Marchand.
— Butylate? Acetal	$C^2H^5,C^4H^9O^2$?	118.	2	59.	59.92	4.141	Stas.
— Butyrate	$C^2H^5,C^4H^7O^2$	116.	2	58.	58.46	4.04	Pelouze and Gelis.
— Caproate	$C^2H^5,C^6H^{11}O^2$	144.	2	72.	71.84	4.965	Fehling.
— Caprylate	$C^2H^5,C^8H^{15}O^2$	172.	2	86.	88.27	6.1	Fehling.
— Carbamate (Urethane)	$C^2H^5,NH^2; CO^2$	89.	2	44.5	45.44	3.14	Dumas.
— — Ethylurethane	$\left\{\begin{array}{l}C^2H^5,NH,C^2H^5;\\ CO^2 \text{ or } H,C^2H^5,\\ C^2H^5;CNO^2\end{array}\right\}$	117.	2	58.5	58.91	4.071	Wurtz.
— Carbonate	$(C^2H^5)^2CO^3$	118.	2	59.	61.4	4.243	Ettling. 4·09
— Chloride	C^2H^5,Cl	64.5	2	32.25	32.11	2.219	Thenard.
— Cinnamate	$C^2H^5,C^9H^7O^2$	176.	2	88.	94.88	6.557	Marchand.
— Cuminate	$C^2H^5,C^{10}H^{11}O^2$	192.	2	96.	96.23	6.65	Gerhardt.
— Cyanate	C^2H^5,CyO	71.	2	35.5	35.81	2.475	Wurtz.
— Cyanurate (Cyanylate)	$C^2H^5,CylO$	71.	$\frac{4}{6}$	106.5	107.1	7.4	Wurtz.
— Œnanthylate	$\left\{\begin{array}{l}C^2H^5,C^7H^{13}O^2\\ +C^2H^5,C^7H^{13}O\end{array}\right\}$	300.	2	150.	152.05	10.508	Liebig and Pelouze.
— Formiate	C^2H^5,CHO^2	74.	2	37.	37.52	2.593	Liebig. 2·573
— — (Tribasic)	$(C^2H^5)^3; CHO^3$	148.	2	74.	75.49	5.217	Kay.
— Hydride	H,C^2H^5	30.	2	15.	15.56	1.075	Frankland.
— Iodide	C^2H^5,I	156.	2	78.	78.38	5.417	Marchand.
Cyanide of Ethyl			2			1·920	

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Ethyl, Laurate	$C^2H^5,C^{12}H^{23}O^2$	228.	2	114.	121.55	8.4	Georgey.
— Nitrite	C^2H^5,NO^2	75.	2	37.5	38.	2.626	Dumas and Boullay.
— Oxalate	C^2H^5,CO^2	73.	1	73.	75.61	5.087	Dumas and Boullay.
— Phosphite (Tribasic)	$(C^2H^5)^3;\ PO^3$	166.	2	83.	83.93	5.8	Railton.
— Pyromucate	$C^2H^5,C^5H^3O^3$	140.	2	70.	70.31	4.859	Malaguti.
— Succinate	$C^2H^5,C^2H^2O^2$	87.	1	87.	88.41	6.11	Cahours.
— Silicate $4(C_2H_5)SiO_4$	C^2H^5,SiO	52.5	½	105.	105.92	7.32	Ebelmen.
— Sulphide	C^2H^5,S	45.	1	45.	44.86	3.1	Regnault.
— Bisulphide	C^2H^5,S^2	61.	1	61.	61.79	4.27	Cahours.
— Hydrosulphide (Mercaptan)	$H,C^2H^5;\ S^2$	62.	2	31.	30.53	2.11	Bunsen. 2:14
— Sulphite	$C^2H^5,C^2H^5;\ S^2O^3$	138.	2	69.	69.17	4.78	Ebelmen.
— Sulphocyanide	$C^2H^5,Cy;\ S^2$	87.	2	43.5	43.67	3.018	Regnault.
— Valerianate	$C^2H^5,C^5H^9O^2$	130.	2	65.	65.95	4.558	Otto.
— and Amyl Oxide	$C^2H^5,C^5H^{11}O$	116.	2	58.	58.49	4.042	Williamson.
— and Methyl Oxide	CH^3,C^2H^5O	60.	2	30.	31.23	2.158	Williamson.
— and Methyl, Oxalate	$CH^3,C^2H^5;\ C^2O^4$	132.	2	66.	67.68	4.677	Chancel.
— -Œnanthyl [Heptyl?] Ether	$C^2H^5,C^7H^{15}O$	144.	2	72.	73.72	5.095	A. W. Wills.
— Zinc-Ethyl	ZnC^2H^5	61.5	1	61.5	61.51	4.251	Frankland.
— Stib-Ethyl	$SbcC^2H^5$	72.	4/6	108.	107.63	7.438	Löwig.
— Arsen-Ethyl	$AscC^2H^5$	54.	4/6	81.	76.38	5.2783	Landolt.
— -Butyl	C^2H^5,C^4H^9	86.	2	43.	44.18	3.053	Wurtz.
— -Amyl	C^2H^5,C^5H^{11}	100.	2	50.	50.96	3.522	Wurtz.
Ethylamine	$NH,C^2H^5;\ H$	45.	2	22.5	22.81	1.5767	Izarn.
Formyl? (Klumene Gas of Gmelin)	CH	13.	1	13.			E. Davy.

Fluorine 1.278 Gay-Lussac

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Formic Acid, at 322° F.	H,CHO^2	46.	2	23.	23.3	1.61	Bunsen.
Furfurol	$H,C^5H^3O^2$	96.	2	48.	48.39	3.344	Cahours.
Hydrogen	H	1.	1	1.	1.002	.06927	Regnault.
Hexyline (Caproiline) (Oleene)	H,C^6H^{11}	84.	2	42.	41.6	2.875	Fremy.
Hexyl (Caproyl?)	C^6H^{13}	85.	1	85.	86.57	5.983	Wurtz.
Iodine	I	127.	1	127.	126.12	8.716	Dumas. 8.65 Bineau
Iodohydric Acid	HI	128.	2	64.	64.29	4.446	Gay-Lussac.
Likene (of Gmelin)	H,C^5H^7 ?	68.	2	34.	34.06	2.354	Couerbe.
Menthene	C^5H^9	69.	1	69.	71.48	4.94	Walter.
Mercury	Hgc	100.	1	100.	100.94	6.976	Dumas. 6.7 Bineau
Mercurous Bromide	HgBr	280.	2	140.	146.73	10.14	Mitscherlich.
— Chloride	HgCl	235.5	2	117.75	120.82	8.35	Mitscherlich.
Mercuric Bromide	HgcBr	180.	1	180.	175.96	12.16	Mitscherlich.
— Chloride	HgcCl	135.5	1	135.5	141.81	9.8	Mitscherlich.
— Iodide	HgcI	227.	1	227.	230.07	~~15.9~~ 16.2	Mitscherlich.
— Sulphide	HgcS	116.	1½	77.33	79.73	~~5.51~~ 5.9	Mitscherlich.
Mesitylol (Mesitylene)	H,C^9H^{11} ?	120.	2	60.	59.99	4.146	Cahours.
Methyl	CH^3	15.	1	15.	15.56	1.075	Frankland & Kolbe.
— Hydride, Marsh Gas	H,CH^3	16.	2	8.	8.07	.5576	Thomson.
— Methylic Ether	CH^3,CH^3O	46.	2	23.	23.4	1.617	Dumas and Peligot.
— Methylic Alcohol	H,CH^3O	32.	2	16.	16.21	1.12	Dumas and Peligot.
— Acetate	$CH^3,C^2H^3O^2$	74.	2	37.	37.09	2.563	Dumas and Peligot.
— Benzoate	$CH^3,C^7H^5O^2$	136.	2	68.	68.25	4.717	Dumas and Peligot.
— Borate (Terbasic)	CH^3,BO	34.6	⅔	51.9	52.96	3.66	Ebelmen.

8.63

2.6140

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Methyl, Bromide	CH^3,Br	95.	2	47·5	45·65	3·155	Bunsen. 4.883
— Butyrate	$CH^3,C^4H^7O^2$	102.	2	51.	50.93	3.52	Pelouze and Gelis.
— Caprylate	$CH^3,C^8H^{15}O^2$	158.	2	79.	78.86	5.45	Fehling.
— Chloride	CH^3,Cl	50.5	2	25.25	25.12	1.736	Bunsen. [illegible]
— Caproate	$CH^3,C^6H^{11}O^2$	130.	2	65.	66.89	4.623	Fehling.
— Cyanide (Acetonitrile)	CH^3,CN	41.	2	20.5	20.98	1.45	Dumas.
— Cyanurate (Cyanylate)	$CH^3,CylO$	57.	$\frac{2}{3}$	85.5	86.53	5.98	Wurtz.
— Sulphocyanide	$CH^3,Cy;S^2$	73.	2	36.5	37·19	2.57	Cahours.
— Fluoride	CH^3,F	34.	2	17.	17.12	1.183	Dumas and Peligot.
— Formiate	CH^3,CHO^2	60.	2	30.	30.16	2.084	Dumas and Peligot.
— — (Tribasic) Formomethylal	$(CH^3)^3,CHO^3$?.	106.	3 ?	35·33	34·83	2.407	Kane.
— -Hexyl	CH^3,C^6H^{13}	100.	2	50.	49·57	3·426	Wurtz.
— Iodide	CH^3,I	142.	2	71.	70.66	4.883	Dumas and Peligot.
— Nitrate	CH^3,NO^3	77.	2	38.5	38.39	2.653	Dumas and Peligot.
— Salicylate	$CH^3,H; C^7H^4O^2$	152.	2	76.	78.43	5.42	Cahours.
— Succinate	$CH^3,C^2H^2O^2$	73.	1	73.	76.55	5.29	Fehling.
— Sulphide	CH^3,S	31.	1	31.	30.6	2.115	Regnault. 3.1
— Bisulphide	CH^3,S^2	47.	1	47.	47·72	3·298	Cahours. 3.310
— Sulphate $2CH_3 \cdot SO_4$	CH^3,SO^2	63.	1	63.	66.06	4.565	Dumas and Peligot.
— Lignone	CH^3,CH^2O ?	45.	2	22.5	26.39	1.824	Kane.
— (Xanthic Ether).	$CH^3,CH^3;CS^4O$	122.	2	61.	61.73	4·266	Cahours.
— Sulphocarbonate	$CH^3,CH^3;CS^4S^2$?	138.	2	69.	67·31	4·652	Cahours.
— Xanthate	$CH^3,C^2H^5; CS^4O$	136.	2	68.	67·31	4·652	Chancel.
— and Amyl Oxide.	$CH^3,C^5H^{11}O$	102.	2	51.	53·97	3·73	Williamson.

Methyl Ethyl Ether

2.158

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Methylal	$CH^3,C^2H^5O^2$	76.	2	38.	37.98	2.625	Malaguti.
Methylamine	$NH,CH^3;H$	31.	2	15.5	15.63	1.08	Wurtz.
Nitrotoluine	C^7H^7,NO^2	137.	2	68.5	71.63	4.95	Deville.
Naphtha	C^3H^5	41.	1	41.	41.	2.833	Saussure.
Naphthaline	$H,C^{10}H^7$	128.	2	64.	65.52	4.528	Dumas.
Nicotine.	NH,C^5H^6?	81.	1	81.	81.13	5.607	Barral.
Nitrogen	N	14.	1	14.	14.06	.97136	Regnault.
— Protoxide	N,NO	44.	2	22.	22.09	1.5269	Thomson. 1.52046 Colin
— Deutoxide	NO	30.	2	15.	15.03	1.0388	Berard.
— Nitrous Acid	N,NO^3	76.					
— Peroxide, Hyponitric Acid	NO^2	46.	2	23.	24.89	1.72	Mitscherlich.
— Anhydrous Nitric Acid	N,NO^5	108.					
— Nitric Acid, Hydrate	$2HNO^3+3HHO$	180.	10 5	18.	18.42	1.273	Bineau.
Œnanthylic Acid	$H,C^7H^{13}O^2$	130.	2	65.	65.62	4.535	Railton.
Œnanthol	$H,C^7H^{13}O$	114.	2	57.	59.33	4.1	Bussy?
Oxygen	O	16.	1	16.	16.	1.10563	Regnault.
Paraffine	$C^{10}H^{21}$?	141.	1	141.	141.7	10.	Lewy.
Petrolene	$C^{10}H^{16}$?	136.	1	136.	136.24	9.415	Boussingault.
Phenyl Hydride (Benzole)	C^6H^5,H	78.	2	39.	40.08	2.77	Mitscherlich.
— Cyanide (Benzonitrile)	C^6H^5,CN	103.	2	51.5	53.54	3.7	Fehling.
— Nitrite (Nitrobenzide)	C^6H^5,NO^2	123.	2	61.5	63.67	4.4	Mitscherlich.
Phosphorus	P	31.	½	62.	63.96	~~4.42~~ 4.35	Dumas.
— Terchloride	PCl^3	137.5	2	68.75	70.54	4.875	Dumas.

4.0/3

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
						3.606	Cruikshanks
Phosphorus, Pentachloride	PCl^5	208.5	3	69.5	70.18	4.85	Mitscherlich.
— Oxychloride	Cl^3PO	153.5	2	76.75	78.14	5.4	Wurtz.
Phosphuretted Hydrogen	PH^3	34.	2	17.	17.05	1.147	H. Rose.
— Hydriodate of	PH^3,HI	162.	4	40.5	40.07	2.769	Bineau.
— Hydrobromate of	PH^3,HBr	115.	4	28.75	27.58	1.906	Bineau.
Propionic Aldide	H,C^3H^5O	58.	2	29.	30.55	2.111	Guckelberger. 2.169
Propylic Alcohol	H,C^3H^7O	60.	2	30.	29.23	2.02	Chancel.
Propyl Butyrate (Butyrone)	C^3H^7,C^4H^7O	114.	2	57.	57.74	3.99	Chancel.
Propylene Bromide?	$H,C^3H^5Br^2$	202.	2	101.	105.8	7.3098	Reynolds.
Propylene	H,C^3H^5	42.	2	21.	21.68	1.498	Berthelot.
Salicylous Acid	$H,H;\ C^7H^4O^2$	122.	2	61.	61.87	4.276	Piria.
Selenious Acid	SeO	56.	1	56.	58.31	4.03	Mitscherlich.
Seleniuretted Hydrogen	HSe	41.	1	41.	40.44	2.795	Bineau.
Silicon, Chloride	$SiCl$	43.	½	86.	85.94	5.939	Pierre.
— Fluoride	SiF	26.5	½	53.	52.09	3.6	Dumas.
— Chlorosulphide	Si^3Cl^2S	109.5	1½	73.	73.51	5.08	Pierre.
Suberone	C^4H^8,C^4H^6O?	126.	2	63.	63.55	4.392	Boussingault.
Sulphur	S	16.	⅙	96.	94.97	6.5635	Dumas.
— Sulphurous Acid	SO	32.	1	32.	32.51	2.247	Berzelius.
— Sulphuric Acid, Anhydrous	S,SO^3	80.	2	40.	43.41	3.01	Mitscherlich.
— — Hydrate	HSO^2 H^2SO^4	49.	2	24.5	24.31	1.58	Bunsen. at
— Hydrosulphuric Acid	HS	17.	1	17.	17.24	1.1912	Gay-Lussac.

at 1900° 6.31 Vol=

at 1900° 2.2

NAME OF GAS.	Composition.	Atomic Weight.	Atomic Measure.	Theoretical Sp. Grav. H = 1.	Observed Sp. Grav. H = 1.	Observed Sp. Grav. Air = 1.	Observer.
Sulphur, Chloride	ClS	51.5	~~1~~ 2	51.5	53.32	3.685	Dumas.
— — Dichloride	ClS^2	67.5	~~1~~	67.5	68.01	~~4.7~~	~~Dumas.~~ 4.77 (Marchand)
— Pentasulphate of Terchloride of Sulphur	$(ClSO)^2+S,SO^3$	215.	4	53.75	64.84	4.481	Rose.
Styrol (Cinnamol)	H,C^8H^7	104.	2	52.	54.48	3.765	Couerbe.
Telluretted Hydrogen	HTe	65.	1	65.	64.97	4.49	Bineau.
Thymyl, Hydride (Cymen)	$H,C^{10}H^{13}$	134.	2	67.	67.29	4.65	Gerhard & Cahours.
Tin, Chloride	$SnCl_4$	2.60 ~~65.~~	2. ~~1~~	130.	133.12	9.1997	Dumas.
Titanium, Chloride	$TiCl$	47.5	½	95.	98.92	6.836	Dumas.
Toluine (Toluol)	H,C^7H^7	92.	2	46.	47.17	3.26	Deville.
Retinnaphtha	H,C^7H^7 ?	92.	2	46.	46.74	3.23	Walter.
Turpentine, Essence.	C^5H^9,C^5H^7	136.	2	68.	68.88	4.76	Dumas.
Valeryl (compounds of):—							
— Valerine (Amylen)	H,C^5H^9	70.	2	35.	34.53	2.386	Frankland
— Valeral	H,C^5H^9O	86.	2	43.	42.4	2.93	Chancel.
— Piperidene	NH,C^5H^9; H	85.	2	42.5	42.8	2.958	Cahours.
— Methylopiperidine	H,NCH^3,C^5H^9.	99.	2	49.5	51.28	3.544	Cahours.
— Ethylopiperidine	H,NC^2H^5,C^5H^9	113.	2	56.5	57.68	3.986	Cahours.
— Valerianic Acid	$H,C^5H^9O^2$	102.	2	51.	53.1	3.67	Dumas and Stas.
Vinyl (Olefiant Gas)	CH^2	14.	1	14.	13.99	.967	W. Henry.
Water	HHO	18.	2	9.	9.02	.6235	Gay-Lussac.
Zinc Ethyl	ZnC^2H^5	61.5	1	61.5	61.51	4.251	Frankland.

No hypothetical specific gravities are given in this Table. No gases are admitted but such as have been actually produced, and, with a few exceptions, weighed. Hence carbon, fluorine, boron, silicon, antimony, zinc, tellurium, &c., are excluded. The Table therefore represents in its weights and measures, a mass of facts. The formulæ alone are theoretical. It enables us to take a comprehensive and trustworthy survey of that chemical region which consists of gases and vapours. It shows us on experimental evidence the weight, the measure, and the ultimate composition, and theoretically the proximate constitution, of above three hundred well-known volatile bodies. Of that large field we have an accurate bird's-eye view. WHAT DO WE SEE THERE?

First of all we perceive, that all the hydrocarbons that act as radicals, all those which in combination displace an atom of hydrogen or of chlorine, have, in an isolated state, an atomic measure of one volume. They are consequently the equivalents of one volume—of one atom—of one equivalent of hydrogen. That is the case with all the radicals that have yet been isolated; with methyl whose specific gravity is 15, with ethyl = 29, with acryl = 41, with butyl = 57, and with amyl, whose specific gravity is 71; all these radicals differing so greatly in their density, have an atomic measure equal to that of hydrogen, whose specific gravity is 1. Dr. Frankland fixed the atomic measures of ethyl, of methyl, and of amyl, at two volumes each, and Dr. Hofmann argued that it ought to be four volumes. But from the peculiar point of view which is recommended in this Essay, the theoretical measure is seen to be only one volume, and the experimental evidence proves that each compound radical is equivalent to one volume of hydrogen.

Secondly, it appears that there are 121 compounds—two-fifths of the whole—which have in common these two properties: they form two volumes of vapour, and they contain two radicals. These radicals are in some cases simple, in others compound; sometimes they are oxidised; sometimes not oxidised; but the compounds all agree in the two leading characters, that there are two radicals in every compound, and that every compound forms two volumes of gas.

By arranging these compounds in *groups*, we shall show clearly the evidence, and the peculiarities, of their binary constitution.

First Group.—Combinations of compound radicals with one another. 7 examples:—

C^4H^9,C^5H^{11}	Butyl-amyl.
C^4H^9,C^6H^{13}	Butyl-hexyl.
C^2H^5,C^4H^9	Ethyl-butyl.
C^2H^5,C^5H^{11}	Ethyl-amyl.
CH^3,C^6H^{13}	Methyl-hexyl.
C^4H^9,C^5H^7 or C^5H^9,C^4H^7	Campholene.
C^9H^{11},C^7H^5	Retinole.

All these radicals belong individually to the class of basic radicals, yet the differences between them are sufficient to enable them to act as basic and acid in respect to one another. The electro-chemical force is still present, perhaps in feeble action, but in action quite sufficient for the purpose of ensuring combination.

Second Group.—Compounds of hydrogen with a compound radical. (*Hydrides.*)

18 Examples:—

H,CH^3	Methyl hydride (marsh gas).
H,C^2H^5	Ethyl hydride.
H,C^3H^5	Propylene.
H,C^4H^7	Butyrine.
H,C^4H^9	Butyl hydride.
H,C^5H^7	Likene.
H,C^5H^9	Valerine (Amylen).
H,C^5H^{11}	Amyl hydride.
H,C^6H^5	Phenyl hydride (Benzine).
H,C^6H^{11}	Hexylene. Caproiline.
H,C^7H^7	Toluine.
H,C^7H^7	Retinnaphtha. *t*
H,C^9H^{11}	Mesitylol.
H,C^9H^{11}	Retinyl?
H,C^8H^{15}	Caprylene. Octylene.
H,C^9H^{11}	Cumenyl hydride.
$H,C^{10}H^{13}$	Thymyl hydride.
$H,C^{16}H^{31}$	Cetene. Palmityl hydride.

Third Group.—Compounds of hydrogen with an oxide of a compound radical; or, it may be, compounds of a compound radical with oxide of hydrogen, thus—CH^3,HO, &c. (*Alcohols. Hydrated oxides. Aldides.*)

18 Examples:—

H,CH^3O	Methylic alcohol.	
H,C^2H^3O	Aldehyd.	
H,C^2H^5O	Alcohol.	
H,C^3H^3O	Acroleine.	
H,C^3H^5O	Acrylic alcohol.	} ?
H,C^3H^5O	Propionic aldide.	
H,C^3H^7O	Propylic alcohol.	
H,C^4H^7O	Butyral.	
H,C^4H^9O	Butylic alcohol.	
H,C^5H^7O	Angelyl hydrate.	
H,C^5H^9O	Valeral.	
$H,C^5H^{11}O$	Amylic alcohol.	
$H,C^6H^{13}O$	Caproic alcohol.	
$H,C^7H^{13}O$	Oenanthol.	
$H,C^7H^{15}O$	Castor oil alcohol.	
$H,C^8H^{17}O$	Caprylic alcohol.	

$H,C^{10}H^{11}O$ . . .	Cumyl hydrate.
$H,C^{10}H^{11}O$ . . .	Essence of anis.

Fourth Group.—Compounds consisting of a compound radical, combined with an oxide of the same radical. (*Ethers. Oxides.*)

3 Examples :—

CH^3,CH^3O . . .	Methylic ether.
C^2H^5,C^2H^5O . . .	Ether.
AsC^2H^6,AsC^2H^6O .	Oxide of cacodyl.

Fifth Group.—Compounds containing a compound radical, combined with an oxide of a different compound radical. (*Compound Ethers and Ketones.*)

12 Examples :—

CH^3,C^2H^3O . . .	Acetone [methyl and acetyl.]
CH^3,CH^2O . . .	Lignone.
CH^3,C^2H^5O . . .	Ethylate of methyl.
$CH^3,C^5H^{11}O$ . . .	Amylate of methyl.
$C^2H^5,C^5H^{11}O$ . .	Amylate of ethyl.
$C^2H^5,C^7H^{15}O$ . .	Ethyl-heptyl ether.
C^3H^7,C^4H^7O . .	Butyrone.
C^2H^5,CNO . . .	Cyanate of ethyl.
C^5H^9,C^5H^7O . . .	Camphor.
C^5H^{11},C^5H^9O ? . .	Peppermint Camphor.
$C^8H^{14},C^8H^{12}O$? . .	Cedrole.
C^4H^8,C^4H^6O ? . .	Suberone.

Sixth Group.—Compounds containing oxide of hydrogen, combined with an oxide of a compound radical. Thus: $HO + CHO = H,CHO^2$. (*Hydrated Organic Acids.*)

9 Examples :—

H,CHO^2	Formic acid.
$H,C^2H^3O^2$ . . .	Acetic acid.
$H,C^4H^7O^2$ . . .	Butyric acid.
$H,C^5H^3O^2$ . . .	Furfurol.
$H,C^5H^9O^2$ . . .	Valerianic acid.
$H,C^6H^{11}O^2$ . . .	Caproic acid.
$H,C^7H^5O^2$ . . .	Benzoic acid.
$H,C^7H^{13}O^2$ . . .	Oenanthylic acid.
$H,C^{10}H^{17}O^2$ . . .	Campholic acid.

Seventh Group.—Compounds containing an oxide of a compound radical, combined with an oxide of a different compound radical. Thus: $CH^3O + CHO = CH^3,CHO^2$. (*Salts of Methyl, Ethyl, Amyl, Butyl, &c., with Organic Acids.*)

21 Examples :—

CH^3,CHO^2 . . .	Methyl, formiate.
$CH^3,C^2H^3O^2$ . .	Methyl, acetate.
$CH^3,C^2H^5O^2$ . .	Methylal.

$CH^3,C^4H^7O^2$	Methyl, butyrate.
$CH^3,C^6H^{11}O^2$	Methyl, caproate.
$CH^3,C^7H^5O^2$	Methyl, benzoate.
$CH^3,C^8H^{15}O^2$	Methyl, caprylate.
C^2H^5,CHO^2	Ethyl, formiate.
$C^2H^5,C^2H^3O^2$	Ethyl, acetate.
$C^2H^5,C^4H^7O^2$	Ethyl, butyrate.
$C^2H^5,C^4H^9O^2$	Ethyl, butylate.
$C^2H^5,C^5H^9O^2$	Ethyl, valerianate.
$C^2H^5,C^6H^{11}O^2$	Ethyl, caproate.
$C^2H^5,C^7H^5O^2$	Ethyl, benzoate.
$C^2H^5,C^8H^{15}O^2$	Ethyl, caprylate.
$C^2H^5,C^9H^7O^2$	Ethyl, cinnamate.
$C^2H^5,C^{10}H^{11}O^2$	Ethyl, cuminate.
$C^2H^5,C^{12}H^{23}O^2$	Ethyl, laurate.
$C^4H^9,C^2H^3O^2$	Butyl, acetate.
$C^5H^{11},C^2H^3O^2$	Amyl, acetate.
$C^5H^{11},C^5H^9O^2$	Amyl, valerianate.

Eighth Group.—Compounds containing an oxide of a metalloid, combined with an oxide of a compound radical. (*Nitrites.*)

4 Examples:—

C^7H^7,NO^2	Nitrite of toluine (nitrobenzoene).
C^2H^5,NO^2	Nitrite of ethyl.
C^6H^5,NO^2	Nitrite of phenyl (nitrobenzide).
C^5H^{11},NO^2	Nitrite of amyl.

Ninth Group.—Compounds consisting of a compound radical, combined with a metalloid. (*Chlorides, Iodides, Bromides, Fluorides, and Cyanides.*)

21 Examples:—

C^2H^3,Cl	Chloride of acetyl.
C^5H^{11},Cl	Chloride of amyl.
C^4H^9,Cl	Chloride of butyl.
AsC^2H^6,Cl	Chloride of cacodyl.
C^2H^5,Cl	Chloride of ethyl.
CH^3,Cl	Chloride of methyl.
C^2H^3,Br	Bromide of acetyl.
C^4H^9,Br	Bromide of butyl.
C^2H^5,Br	Bromide of ethyl.
CH^3,Br	Bromide of methyl.
C^2H^3,I	Iodide of acetyl.
C^5H^{11},I	Iodide of amyl.
C^4H^9,I	Iodide of butyl.
C^2H^5,I	Iodide of ethyl.
CH^3,I	Iodide of methyl.
CH^3,F	Fluoride of methyl.

C^5H^{11},Cy . . .	Cyanide of amyl.
AsC^2H^6,Cy . . .	Cyanide of cacodyl.
$C\,H^3,Cy$ . . .	Cyanide of methyl.
C^4H^9,Cy . . .	Cyanide of butyl.
C^6H^5,Cy . . .	Cyanide of phenyl.

Tenth Group.—Compounds containing a compound radical, combined with an oxide of a metalloid. (*Oxychlorides*, &c.)

2 Examples:—

C^7H^5,ClO . . .	Chloride of benzoile.
C^2H^3,ClO . . .	Oxychloride of acetyl.

Eleventh Group.—Compounds of various orders, all containing three atoms of oxygen.

6 Examples:—

$C^2H^3,C^2H^3O^3$ . .	Anhydrous acetic acid.
$C^4H^7,C^4H^7O^3$ . .	Anhydrous batyric acid.
$C^2H^5,C^2H^5;\ C\,O^3$.	Carbonate of ethyl.
$C^2H^5,C^2H^5;\ S^2O^3$.	Sulphite of ethyl.
$C^2H^5,C^5H^3O^3$ . .	Pyromucate of ethyl.
$C\,H^3,NO^3$ . . .	Nitrate of methyl.

The compounds enumerated in these eleven groups amount to 121. Their properties are remarkable. They all contain two radicals. They all produce two volumes of gas. Most of them contain two compound radicals. A few contain one simple and one compound radical. When these radicals are isolated, each of them (as far as our knowledge extends), forms a single volume of gas: consequently, they all combine with one another without suffering condensation. The relation of the compounds to oxygen is as follows:—46 of them contain no oxygen; 35 contain one atom; 34 contain two atoms; and 6 contain three atoms of oxygen. Whatever the quantity of oxygen present, each compound has merely the gaseous volume that is proper to its two radicals. This is equally the case, whether the radicals are simple or compound, whether the quantity of oxygen is one, or two, or three atoms, or none. The oxygen increases the weight of the radical, but adds nothing to its measure. With hydrogen the results are entirely different. *Any quantity* of carbon and hydrogen, which is combined by the organising powers of nature into a compound radical,—from *two* atoms (Formyl = CH) up to *thirty-five* atoms (Lauryl = $C^{12}H^{23}$) is condensed into a single volume of gas, which is chemically equivalent to a single volume of hydrogen; but we cannot experimentally combine with one of these radicals another volume of hydrogen without producing a hydride which measures two volumes. Thus, oxygen, which, when separated from other elements, can be obtained only in the state of gas when it goes into gaseous combination with compound radicals, loses its volume, and adds only to the weight of the compound, and nothing to the measure. How is it that this remarkable fact has hitherto escaped the notice of chemists? Is it not a powerful argument in support of the theory of the separate existence of the compound radicals? The difference between oxygen and all other elements proves clearly that oxygen is not a *radical*, and is never the *equivalent* of a radical; not one of the 121 salts enumerated in the foregoing groups, can exchange either of its radicals for oxygen, though radicals can be substituted for radicals, either single or compound, to any extent whatever. Hence, all the arguments that have been urged in favour of the hypotheses, that one volume of oxygen is the equivalent of two volumes of hydrogen and of two volumes of chlorine, fall to the ground.

From the facts disclosed by this survey, I think we may draw the general conclusions, that all *salts* are BINARY; that they are compounds formed of *two radicals*, which may be simple or compound, oxidised or not oxidised.

The evidence that has been brought forward in support of this theory is twofold; first, that which consists in an attempted refutation of the hypothesis of sesquioxides, and secondly, the evidence supplied by the physical constitution of the gases, and which may be termed the *argument from gaseous volumes.* The evidence that would be obtained by comparing the compounds that are volatile, with the immense mass of corresponding organic compounds that are not volatile, may be called the *argument from analogy.* It is an argument of great weight, but its comprehensiveness unfits it for the limits of this Essay. I shall in the following pages adduce a few, but only a few, illustrations of this character.

The radical theory modifies in a peculiar degree the chemical character which is usually ascribed to oxygen. Hitherto, chemists have been accustomed to consider oxygen as a centre round which all other elements gyrated—the sun of the chemical planetary system. But the radical theory proves to us, that the substantive elements of a salt, whether it is acid, alkaline, or neutral, are the two radicals which it contains. Without two radicals there can be no salt. Without oxygen we can have many salts. Any two radicals, simple or compound, can form a salt, with no oxygen, with one atom, or two, or three, or four atoms of oxygen. The equivalency of the radicals is not affected by the presence or absence of oxygen. Those salts which have no oxygen are as perfect in their characters as those which have much oxygen. Those salts which are gaseous have no increase in volume from the acquisition of oxygen. A volume of hydrogen in combination (not forming part of a radical) measures a volume, so does a volume of chlorine. One, two, or three volumes of oxygen in combination, measure nothing. Oxygen, therefore, is not a radical, or *salt-former*, in the sense in which hydrogen, chlorine, the metals, and the hydrocarbons are radicals. A volume of it is not the equivalent, either of one volume, or of two volumes of hydrogen or of chlorine. Its action is peculiar to itself, and not a property which it holds in common with other elements. In forming our notions of salts, and in framing our plans for their classification, we should consequently do so without regard to the presence or absence of oxygen. For that reason, we say that a compound of two radicals is a salt, whether the radicals are oxidised or not. And by enlarging our conception of the word "radical," so that it signifies either elements or compound radicals, we are provided with a theory of the salts that applies equally to inorganic and to organic chemistry.

Oxygen is not only unnecessary to the existence of a salt, but it is not even the *acid-former* in the sense that many chemists so consider it. Even among inorganic compounds, oxygen, as was many years ago pointed out by Davy, is not the cause of acidity. Chlorate of potassium = KCl is a neutral salt, and when three atoms of oxygen are added, producing chlorate of potash = $KClO^3$, the salt is still neutral. The hydrate of chloric acid = $HClO^3$ is an acid. Remove all the oxygen, leaving hydrochloric acid = HCl, and the compound is still acid. So, among compound organic radicals, the presence or the quantity of oxygen is not the cause of acidity. An acid requires the presence of an acid radical. An acid radical can sometimes be produced by the action of oxygen on non-acid compounds, but even then the acid is seldom the result of the mere addition of oxygen. Other circumstances operate to this end, and, among these, one of the most important, as respects the hydrocarbons, is the *right apportionment of their hydrogen to their carbon.* In illustration of this point, the following Table presents a selection of compound radicals, arranged in such a manner as to show this relation—the radicals which contain the greatest relative quantity of hydrogen being placed first in the list:—

Ratios.		Formulæ.	Radicals.	Salts containing the Radicals.
C.	H.			
1	3·	$C\ H^3$	Methyl.	
1	2·5	$C^2\ H^5$	Ethyl.	
1	2·333	$C^3\ H^7$	Propyl.	
		$C^3\ H^7$	Lipyl.	
1	2·25	$C^4\ H^9$	Butyl.	
1	2·2	$C^5\ H^{11}$	Amyl.	
1	2·167	$C^6\ H^{13}$	Hexyl.	
1	2·143	$C^7\ H^{15}$	Heptyl.	
1	2·125	$C^8\ H^{17}$	Octyl.	
1	2·067	$C^{15}H^{31}$		Palmitone.
1	2·062	$C^{16}H^{33}$	Cetyl.	
1	2·037	$C^{27}H^{55}$	Ceryl.	
1	2·033	$C^{30}H^{61}$	Myricyl.	
1	2·	$C\ H^2$	Olefiant Gas (Vinyl).	

Ratios.		Formulæ.	Radicals.	Salts containing the Radicals.
C.	H.			
1	1·967	$C^{30}H^{59}$	Melissyl	Melissic Acid.
1	1·963	$C^{27}H^{53}$		Cerotic Acid.
1	1·952	$C^{21}H^{41}$		Behenic Acid.
1	1·95	$C^{20}H^{39}$		Arachidic Acid.
1	1·947	$C^{19}H^{37}$		Balenic Acid.
1	1·944	$C^{18}H^{35}$		Stearic Acid.
1	1·941	$C^{17}H^{33}$		Margaric Acid.
1	1·937	$C^{16}H^{31}$	Palmityl	Palmitic Acid.
1	1·933	$C^{15}H^{29}$		Benic Acid.
1	1·928	$C^{14}H^{27}$	Myristyl	Myristic Acid.
1	1·923	$C^{13}H^{25}$	Cocinyl	Cocinic Acid.
1	1·916	$C^{12}H^{23}$	Lauryl	Lauric Acid.
1	1·909	$C^{11}H^{21}$		Margaritic Acid.
1	1·9	$C^{10}H^{19}$	Rutyl	Rutic Acid.
				Capric Acid.
1	1·889	$C^{9}H^{17}$	Pelargyl	Pelargonic Acid.
1	1·875	$C^{8}H^{15}$	Capryl	Caprylic Acid.
1	1·857	$C^{7}H^{13}$	Oenanthyl	Oenanthylic Acid.
1	1·833	$C^{6}H^{11}$	Caproyl	Caproic Acid.
				Glucosic Acid.
		$C^{18}H^{33}$		Oleic Acid.
				Ricinolic Acid.
1	1·8	$C^{5}H^{9}$	Valeryl	Valerianic Acid.
1	1·75	$C^{4}H^{7}$	Butyryl	Butyric Acid.
1	1·7	$C^{10}H^{17}$	Camphyl	Campholic Acid.
1	1·667	$C^{3}H^{5}$	Acryl ?	Acrylic Alcohol.
			Allyl ?	
			Propionyl	Propionic Acid.
				Lactic Acid.
				Metacetonic Acid.
1	1·6	$C^{5}H^{8}$		Sebacic Acid.
1	1·5	$C^{2}H^{3}$	Acetyl	Acetic Acid.
				Homolactic Acid.
				Glycollic Acid.
		$C^{4}H^{6}$	Suberyl	Suberic Acid.
1	1·429	$C^{7}H^{10}$		Pimelic Acid.
1	1·4	$C^{5}H^{7}$	Angelyl	Angelic Acid.
			Camphoryl	Camphoric Acid.
1	1·333	$C^{3}H^{4}$		Mucic Acid.
				Adipic Acid.
1	1·3	$C^{10}H^{13}$	Thymyl.	

Ratios.		Formulæ.	Radicals.	Salts containing the Radicals.
C.	H.			
1	1·286	$C^{7}H^{9}$	. .	Kinic Acid.
1	1·25	$C^{4}H^{5}$	. .	Isotartaric Acid.
1	1·222	$C^{9}H^{11}$	Cumenyl.	
		$C^{9}H^{11}$	Mesityl.	
1	1·2	$C^{5}H^{6}$	. .	Pyrotartaric Acid.
1	1·1	$C^{10}H^{11}$	Cumyl . . .	Cuminic Acid.
1	1·	$C^{1}H^{1}$	Formyl . . .	Formic Acid.
		$C^{1}H^{1}$	Pteleyl.	
		$C^{2}H^{2}$	. .	Succinic Acid.
			. .	Tartaric Acid.
		$C^{3}H^{3}$	Acryl? . . .	Acrylic Acid.
			. .	Pyruvic Acid.
		$C^{4}H^{4}$	. .	Malic Acid.
			. .	Metatartaric Acid.
		$C^{7}H^{7}$	Toluenyl.	
		$C^{9}H^{9}$	Styryl.	
1	0·875	$C^{8}H^{7}$	Anisyl . . .	Anisic Acid.
			Toluyl . . .	Toluic Acid.
1	0·833	$C^{6}H^{5}$	. .	Citric Acid.
			Phenyl . . .	Phenic Acid.
1	0·8	$C^{5}H^{4}$	. .	Citraconic Acid.
1	0·778	$C^{9}H^{7}$	Cinnamyl . .	Cinnamic Acid.
1	0·75	$C^{4}H^{3}$	. .	Tartrelic Acid.
1	0·714	$C^{7}H^{5}$	Benzyl . . .	Benzoic Acid.
1	0·6	$C^{5}H^{3}$	. .	Pyromeconic Acid.
			. .	Pyromucic Acid.
			. .	Furfurol.
1	0·571	$C^{7}H^{4}$	Salicyl . . .	Salicylic Acid.
1	0·5	$C^{8}H^{4}$	. .	Aconitic Acid.
			. .	Fumaric Acid.
			. .	Maleic Acid.
		$C^{4}H^{2}$	. .	Phtalic Acid.
			. .	Tartaric Acid.
			. .	Tartrelic Acid.
		$C^{6}H^{3}$	. .	Comenic Acid?
1	0·429	$C^{7}H^{3}$	. .	Gallic Acid?
1	0·333	$C^{6}H^{2}$	. .	Comenic Acid?
1	0·143	$C^{7}H^{1}$	. .	Meconic Acid.
			. .	Chrysammic Acid.

Taking into consideration the properties and the composition of the compounds named in this list, we seem to be warranted in drawing the following conclusions:

1. That carbon acts as an acid radical; that hydrogen acts as a basic radical; and that radicals containing the two elements act as acid or basic, according as the carbon or the hydrogen exceeds a certain proportion.

2. That the compound CH^2 is one in which the acid properties of the carbon are neutralized by the basic properties of the hydrogen. This compound is *olefiant gas*, called by Berzelius *elayl*, and by Gmelin *vine*, a term which might with convenience be translated into VINYL, which term I propose to employ.

3. Compound radicals that contain any proportion of hydrogen *greater* than that of H^2 to C^1, are BASIC. Those that contain any proportion of hydrogen *less* than that of H^2 to C^1, are *acid*. Thus—

$C^{30}H^{61}$ = Myricyl . . A basic radical.
CH^2 = Vinyl . . Neutral.
$C^{30}H^{59}$ = Melissyl . . An acid radical.

Hence the basic radicals occur in the above list before Vinyl, and the acid radicals after it. I speak only in a general sense, and do not mean to give to this observation the character of a fixed and absolute law. But supposing the law to be only approximately true, this list, notwithstanding its irregularities, may serve in organic chemistry the same purpose that Berzelius's electro-chemical arrangement of the elements serves in inorganic chemistry, namely, as a formal guide in the arrangement of basic and acid radicals. Notwithstanding the irregularities, it is evident that we may, with propriety, decide between any two radicals, that the one which contains the greater proportion of hydrogen is the more basic of the two. According to this rule, methyl is more basic than ethyl, ethyl than propyl, propyl than amyl, and so on, through the whole range of the hydrocarbons. There are exceptions to this rule, but perhaps not more than occur in Berzelius's electro-chemical list of the elements. It is a great point gained, if, setting oxygen aside, we can, from the mere inspection of the formulæ of the hydrocarbons, distinguish the basic from the acid.

The present uncertain practice of chemists in their dealings with salt radicals, shows the necessity of adopting some decisive method of distinguishing the basic radicals from the acid. When Professor Williamson discovered his compound ethers, he was unable to name them in accordance with any commonly understood system; and consequently he gave to each compound *a series of synonymes*. Thus the compound which contained $\begin{matrix}C^2H^5\\CH^3\end{matrix}O$ was called the *three carbon ether*, the *ethylate of methyle*, and the *methylate of ethyle*. Now upon the principle that we have just laid down, methyl must, in all cases, be held to be basic against ethyl, the relation of the hydrogen to the carbon being 3 to 1 against 2½ to 1. Hence, the difficulty of naming the compound is avoided, and our memories are spared the infliction of useless synonymes.

It would be easy to refer to innumerable examples in the writings of Gerhardt, which show the want of this principle of classification. He finds, for example, a compound containing benzyl and acetyl, with three atoms of oxygen,[1] $= C^2H^3 + C^7H^5 + O^3$, and he calls it "*acetic benzoate* or *benzoic acetate.*" Again, he finds a similar compound containing acetyl and cumenyl $= C^2H^3 + C^{10}H^{11} + O^3$, and he is uncertain whether to call it *acetic cuminate* or *cuminic acetate*. Such difficulties are immediately resolved by the rule that has been proposed, according to which acetyl is to be considered as decidedly basic towards both benzyl and cuminyl.

It is not proposed to investigate in systematic detail the proximate composition of the compound radicals, but in reference to the question whether oxygen is the acidifying principle, and to one or two doctrines that depend upon the answer to that question, it will be useful to adduce a few special illustrations.

Reduction of Basic Radicals to Acid Radicals.

A remarkable relation exists between many basic radicals and acid radicals, taken in pairs. Vinyl = CH^2 being the point of neutrality, certain basic radicals taken from above it in the list, are related to particular acid radicals taken from below it, the difference in composition between the pair being that of two atoms of hydrogen. Examples:—

Basic Radicals. *Acid Radicals.*

Methyl $= C\,H^3 - H^2 = C\,H$ = Formyl.
Ethyl $= C^2H^5 - H^2 = C^2H^3$ = Acetyl.
Propyl $= C^3H^7 - H^2 = C^3H^5$ = Propionyl.
Butyl $= C^4H^9 - H^2 = C^4H^7$ = Butyryl.
Amyl $= C^5H^{11} - H^2 = C^5H^9$ = Valeryl.
Myricyl $= C^{30}H^{61} - H^2 = C^{30}H^{59}$ = Melissyl.

From this it appears that a BASIC *Hydrocarbon*—no matter what may be the complexity of its composition, is, according to theory, convertible into an ACID *Hydrocarbon* by any process which withdraws from it two atoms of hydrogen, that being the constant difference between a basic radical of the kind referred to and its corresponding acid radical.

Is this theoretical vision practically true? Can we convert a basic radical into an acid radical, by withdrawing from it two atoms of hydrogen? If the answer to that question is yes, then the process of acidification—I am speaking of the acidification of hydrocarbons only—consists, not simply in the *addition of oxygen*, but primarily and essentially in the *abstraction of two atoms of hydrogen* from the compound radical that is to be acidified. The answer to the inquiry is, practically, in the affirmative, as regards a considerable class of radicals. Any chemical agent, or even a physical agent, such as the galvanic current, which can separate from a basic radical of the kind referred to two atoms of hydrogen produces an acid radical, or performs the essential part of the operation which is termed *acidification*. Oxygen, therefore, though the common agent of acidification, and chiefly because of the facility with which it converts two atoms of hydrogen into an atom of water and so removes them, is not essentially the acidifying principle. Chlorine can be made an acidifying principle; the galvanic-battery can be made an acidifying principle; for both can separate hydrogen from a basic radical, and so convert it into an acid radical.

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[1] Quarterly Journal of the Chemical Society (1852), V. 227.

Reduction of Acid Radicals to Basic Radicals.

If we examine in a cursory manner the composition of the radicals just referred to, we find that the basic radicals appear to consist of a multiple of vinyl = CH^2, added to a single atom of hydrogen = H, while the acid radicals appear to consist of a multiple of vinyl = CH^2, added to a single atom of formyl = CH. It follows, that if we can take from an acid radical a single atom of carbon = C, we can destroy its chemical character, and convert it into a basic radical. Take the cases just cited:—

Acid Radicals. *Basic Radicals.*
Formyl = $CH - C = H$ = Hydrogen.
Acetyl = $C^2H^3 - C = CH^3$ = Methyl.
Propionyl = $C^3H^5 - C = C^2H^5$ = Ethyl.
Butyryl = $C^4H^7 - C = C^3H^7$ = Propyl.
Valeryl = $C^5H^9 - C = C^4H^9$ = Butyl.

Hence we have it, *theoretically*, in our power, by an alternate abstraction from a radical of H^2 and C^1 to make it alternately acid or basic, through a regular course of reductions till we come at last to the elementary basic radical H; for—

Amyl $- H^2$ is Valeryl.
Valeryl $- C$,, Butyl.
Butyl $- H^2$,, Butyryl.
Butyryl $- C$,, Propyl.
Propyl $- H^2$,, Propionyl.
Propionyl $- C$,, Ethyl.
Ethyl $- H^2$,, Acetyl.
Acetyl $- C$,, Methyl.
Methyl $- H^2$,, Formyl.
Formyl $- C$,, Hydrogen.

Experimental Reduction of Radicals.

What is here assumed to be theoretically possible, can, to a certain extent—I do not know to how limited an extent—be performed experimentally. Kolbe has shown[1] that by the electrolysis of a valerianate $= K,C^5H^9O^2$, valeryl $= C^5H^9$ is converted into butyl $= C^4H^9$, and that by the electrolysis of an acetate $= K,C^2H^3O^2$, acetyl $= C^2H^3$ is converted into methyl $= CH^3$, the extra atom of carbon being driven off in the state of carbonic acid.

"Particular interest," says Professor Miller,[2] "is attached to these researches, owing to the circumstance that in each case the compounds obtained by the electrolysis belong to a series related to an alcohol different from that which was submitted to decomposition. The valerianic acid thus yields an ether of the butylic series; and acetic acid, which is a derivative of wine alcohol, furnishes the carbo-hydrogen which belongs to the wood-spirit series."

Brazier and Gossleth have shown[3] that by the electrolysis of a caproate $= K, C^6H^{11}O^2$, caproyl $= C^6H^{11}$ is converted into amyl $= C^5H^{11}$, and that by the electrolysis of an œnanthylate $= K, C^7H^{13}O^2$, œnanthyl $= C^7H^{13}$ is converted into hexyl $= C^6H^{13}$, with evolution of carbonic acid.

In all these examples, acid radicals are reduced to basic radicals by the abstraction of C^1.

Similar transformations can be effected chemically; as, for example, by the joint action of heat and fixed alkalies. Thus, Professor Brodie, by heating the hydrate of myricyl $= H, C^{30}H^{61}O$, with lime and potash converted it into melissate of potash $= K, C^{30}H^{59}O^2$, in which process the basic radical $C^{30}H^{61}$ loses two atoms of hydrogen, and is reduced to the acid radical $C^{30}H^{59}$. In the same manner, the hydrate of ceryl $= H,C^{27}H^{55}O$ was converted into cerotate of potash $= K, C^{27}H^{53}O^2$, where the radical ceryl $= C^{27}H^{55}$ is reduced by the abstraction of H^2 to another radical not yet named $= C^{27}H^{53}$. Dumas and Stas, by acting in this manner on ethal, or hydrate of cetyl $= H, C^{16}H^{33}O$ converted it into palmitate of potash $= K, C^{16}H^{31}O$ where the radical cetyl $= C^{16}H^{33}$ is reduced to the radical palmityl $= C^{16}H^{31}$. In all these examples basic radicals are reduced to acid radicals by the abstraction of H^2. This process in the ordinary language of organic chemistry is called "oxidation."

The Ketones.

In this manner also the KETONES are prepared.[4] Here, again, we have acid radicals reduced to basic radicals by the abstraction of C^1.

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[1] Chemical Soc. Quarterly Journal, II., 157.
[2] Elements of Chemistry (1856), Part II., 1120.
[3] Chemical Soc. Quarterly Journal, III., 210.
[4] Gmelin, Handbook of Chemistry, VII., 136.

Compounds exposed to Heat. Compounds produced. Constant product.

$$\left.\begin{array}{llcl}
\text{A.} & K,C^2H^3O^2 + K,C^2H^3O^2 & = & C\,H^3, C^2H^3O \\
\text{B.} & K,C^3H^5O^2 + K,C^3H^5O^2 & = & C^2H^5, C^3H^5O \\
\text{C.} & K,C^4H^7O^2 + K,C^4H^7O^2 & = & C^3H^7, C^4H^7O \\
\text{D.} & K,C^5H^9O^2 + K,C^5H^9O^2 & = & C^4H^9, C^5H^9O \\
\text{E.} & K,C^7H^5O^2 + K,C^7H^5O^2 & = & C^6H^5, C^7H^5O \\
\text{F.} & K,C^{10}H^{17}O^2 + K,C^{10}H^{17}O^2 & = & C^9H^{17}, C^{10}H^{17}O \\
\text{G.} & K,C^{17}H^{33}O^2 + K,C^{17}H^{33}O^2 & = & C^{16}H^{33}, C^{17}H^{33}O \\
\text{H.} & K,C^5H^9O^2 + K,C^2H^3O^2 & = & C^4H^9, C^2H^3O
\end{array}\right\}^{1} + K^2CO^3$$

In every example two atoms of salt are decomposed, because the carbonate of potash to be produced is bibasic = $KKCO^3$. The salts are submitted to dry distillation; the ketones form a distillate, and the fixed carbonate of potash remains behind. One of the compounds loses a single atom of carbon, and is thus reduced from an acid radical to a basic radical. Three atoms of oxygen go off with the carbon, leaving one atom with the ketone, which therefore consists in each case of an unoxidised basic radical, combined with an oxidised acid radical, constituting a compound of the same nature as the compound ethers described in Group 5, page 66.

In A. Acetyl = C^2H^3 is reduced to Methyl = $C\,H^3$
B. Propionyl = C^3H^5 ,, Ethyl = C^2H^5
C. Butyryl = C^4H^7 ,, Propyl = C^3H^7
D. Valeryl = C^5H^9 ,, Butyl = C^4H^9
E. Benzyl = C^7H^5 ,, Phenyl = C^6H^5
F. Camphyl = $C^{10}H^{17}$,, Pelargyl = C^9H^{17}
G. Margaryl = $C^{17}H^{33}$,, Cetyl = $C^{16}H^{33}$
H. Valeryl = C^5H^9 ,, Butyl = C^4H^9

The names usually given to these ketones are as follow:—A, acetone.—B, propione.—C, butyrone.—D, valerone.—E, benzone.—F, campholone.—G, margarone.—H. There is a difficulty respecting this ketone, because it is unknown whether the atom of carbon is abstracted from the valeryl or the acetyl. Williamson gives the formula $\begin{matrix}CH_3\\C_4H_9\end{matrix}CO$, which admits the ketone to contain butyl, methyl, and oxide of carbon, a composition that is by no means probable. Gerhardt says of it,[2] that "it is evidently the valeride of methyl or the acetylide of butyl," a description which sufficiently shows the difficulty of choice. However, whether this particular ketone is to be written C^4H^9,C^2H^3O, or CH^3,C^5H^9O, the result is the same in regard to my present argument, which is to prove that certain acid radicals can be reduced to basic radicals by the abstraction of one atom of carbon.

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[1] H is the result of an experiment made by Professor Williamson, Quarterly Journal Chem. Soc. IV., 239.

[2] Traité de Chimie Organique, II., 650.

The Aldehydes.

Experiments of a character precisely similar to the foregoing have been described by Limpricht and Ritter,[1] in reference to the production of the class of compounds called *aldehydes* or *aldides*. If formiate of lime = Ca,CHO^2 is heated with the lime-salt of another acid, the formyl is decomposed. Its carbon produces carbonic acid, and its hydrogen becomes a basic radical to the acid radical of the other salt. Thus—

$$Ca, CHO^2 \quad + \quad Ca, C^2H^3O^2 \quad = \quad CaCa, CO^3 \quad + \quad H, C^2H^3O$$

Formiate of lime. Acetate of lime. Carbonate of lime. Aldehyde.

According to Ritter this reduction of formyl to hydrogen has been effected experimentally with all the following compounds:—

$$Ca, CHO^2 \quad + \quad Ca, C^3H^5O^2 \quad = \quad CaCa, CO^3 \quad + \quad H, C^3H^5O$$

Propionate of lime. Propylaldehyde.

$$Ca, CHO^2 \quad + \quad Ca, C^5H^9O^2 \quad = \quad CaCa, CO^3 \quad + \quad H, C^5H^9O$$

Valerate of lime. Valeraldehyde.

$$Ca, CHO^2 \quad + \quad Ca, C^7H^{13}O^2 \quad = \quad CaCa, CO^3 \quad + \quad H, C^7H^{13}O$$

Oenanthylate of lime. Oenanthol.

$$Ca, CHO^2 \quad + \quad Ca, C^8H^{15}O^2 \quad = \quad CaCa, CO^3 \quad + \quad H, C^8H^{15}O$$

Caprylate of lime. Caprylaldehyde.

In all these cases an acid radical is reduced to a basic radical by the abstraction of C^1.

This evidence to prove the experimental reduction of compound radicals from acid to basic, and from basic to acid, by the alternate abstraction of C^1 and H^2, has been adduced because the subject does not appear to be clearly apprehended by many chemists. Even Gmelin advances opinions that are in some respects adverse to these facts. Thus, in speaking of the transformations of organic compounds, he says,[2] that "they may take place by the complete or partial abstraction of one or more constituents (CARBON EXCEPTED)." And, again, "The carbon of an organic compound cannot be removed by substitution; for this element is the one essential principle of organic compounds; the number of its atoms determines their character, and no other substance can take its place. Without carbon nothing organic can exist! Even *the diminution of the number of its atoms in a compound* would immediately remove that compound into another series, and alter its character entirely."

The Vinyl Series of Radicals.

It would take me too far into details to enter into the consideration of the transformation of organic radicals generally. The facts that I have adduced show evidently the distinction of radicals into basic and acid; how each kind can be converted into the other, and how totally independent of mere oxidation is the discrimination of radicals into these two classes.

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[1] Quarterly Journal of the Chemical Society (1856), IX., 188.

[2] Handbook of Chemistry, VII., 71.

It is, however, so highly interesting to observe the relationship of the hydrocarbons one to another, that I must bring forward a *single complete* SERIES, in order to collect and confirm the facts which I have brought forward in detail.

				Radicals.	*Their Salts.*
			$C^{30}H^{61}$	Myricyl	Hydrate of myricyl
$C^{30}H^{61}$	$- H^{2}$	=	$C^{30}H^{59}$	Melissyl	Melissic acid
$C^{30}H^{59}$	$- C$	=	$C^{29}H^{59}$		
$C^{29}H^{59}$	$- H^{2}$	=	$C^{29}H^{57}$		
$C^{29}H^{57}$	$- C$	=	$C^{28}H^{57}$		
$C^{28}H^{57}$	$- H^{2}$	=	$C^{28}H^{55}$		
$C^{28}H^{55}$	$- C$	=	$C^{27}H^{55}$	Ceryl	Hydrate of ceryl
$C^{27}H^{55}$	$- H^{2}$	=	$C^{27}H^{53}$	. .	Cerotic acid
$C^{27}H^{53}$	$- C$	=	$C^{26}H^{53}$		
$C^{26}H^{53}$	$- H^{2}$	=	$C^{26}H^{51}$		
$C^{26}H^{51}$	$- C$	=	$C^{25}H^{51}$		
$C^{25}H^{51}$	$- H^{2}$	=	$C^{25}H^{49}$		
$C^{25}H^{49}$	$- C$	=	$C^{24}H^{49}$		
$C^{24}H^{49}$	$- H^{2}$	=	$C^{24}H^{47}$		
$C^{24}H^{47}$	$- C$	=	$C^{23}H^{47}$		
$C^{23}H^{47}$	$- H^{2}$	=	$C^{23}H^{45}$		
$C^{23}H^{45}$	$- C$	=	$C^{22}H^{45}$		
$C^{22}H^{45}$	$- H^{2}$	=	$C^{22}H^{43}$		
$C^{22}H^{43}$	$- C$	=	$C^{21}H^{43}$		
$C^{21}H^{43}$	$- H^{2}$	=	$C^{21}H^{41}$	. .	Behenic acid
$C^{21}H^{41}$	$- C$	=	$C^{20}H^{41}$		
$C^{20}H^{41}$	$- H^{2}$	=	$C^{20}H^{39}$	. .	Arachidic acid
$C^{20}H^{39}$	$- C$	=	$C^{19}H^{39}$		
$C^{19}H^{39}$	$- H^{2}$	=	$C^{19}H^{37}$	. .	Balenic acid
$C^{19}H^{37}$	$- C$	=	$C^{18}H^{37}$		
$C^{18}H^{37}$	$- H^{2}$	=	$C^{18}H^{35}$	. .	Stearic acid
$C^{18}H^{35}$	$- C$	=	$C^{17}H^{35}$		
$C^{17}H^{35}$	$- H^{2}$	=	$C^{17}H^{33}$	Margaryl	Margaric acid
$C^{17}H^{33}$	$- C$	=	$C^{16}H^{33}$	Cetyl	Ethal is its hydrate
$C^{16}H^{33}$	$- H^{2}$	=	$C^{16}H^{31}$	Palmityl	Palmitic acid
$C^{16}H^{31}$	$- C$	=	$C^{15}H^{31}$	. .	Palmitone
$C^{15}H^{31}$	$- H^{2}$	=	$C^{15}H^{29}$	. .	Benic acid
$C^{15}H^{29}$	$- C$	=	$C^{14}H^{29}$		
$C^{14}H^{29}$	$- H^{2}$	=	$C^{14}H^{27}$	Myristyl	Myristic acid
$C^{14}H^{27}$	$- C$	=	$C^{13}H^{27}$	. .	Myristone
$C^{13}H^{27}$	$- H^{2}$	=	$C^{13}H^{25}$	Cocinyl	Cocinic acid
$C^{13}H^{25}$	$- C$	=	$C^{12}H^{25}$		

$C^{12}H^{25} - H^2 = C^{12}H^{23}$	Lauryl	Lauric acid
$C^{12}H^{23} - C = C^{11}H^{23}$	. .	Laurone
$C^{11}H^{23} - H^2 = C^{11}H^{21}$	. .	Margaritic acid
$C^{11}H^{21} - C = C^{10}H^{21}$		
$C^{10}H^{21} - H^2 = C^{10}H^{19}$	Rutyl	Rutic acid
$C^{10}H^{19} - C = C^{9}H^{19}$		
$C^{9}H^{19} - H^2 = C^{9}H^{17}$	Pelargyl	Pelargonic acid
$C^{9}H^{17} - C = C^{8}H^{17}$	Octyl	Caprylic alcohol
$C^{8}H^{17} - H^2 = C^{8}H^{15}$	Capryl	Caprylic acid
$C^{8}H^{15} - C = C^{7}H^{15}$	Heptyl	Castor oil alcohol
$C^{7}H^{15} - H^2 = C^{7}H^{13}$	Œnanthyl	Œnanthylic acid
$C^{7}H^{13} - C = C^{6}H^{13}$	Hexyl	Caproic alcohol
$C^{6}H^{13} - H^2 = C^{6}H^{11}$	Caproyl	Caproic acid
$C^{6}H^{11} - C = C^{5}H^{11}$	Amyl	
$C^{5}H^{11} - H^2 = C^{5}H^{9}$	Valeryl	Valerianic acid
$C^{5}H^{9} - C = C^{4}H^{9}$	Butyl	
$C^{4}H^{9} - H^2 = C^{4}H^{7}$	Butyryl	Butyric acid
$C^{4}H^{7} - C = C^{3}H^{7}$	Propyl	
$C^{3}H^{7} - H^2 = C^{3}H^{5}$	Propionyl	Propionic acid
$C^{3}H^{5} - C = C^{2}H^{5}$	Ethyl	
$C^{2}H^{5} - H^2 = C^{2}H^{3}$	Acetyl	Acetic acid
$C^{2}H^{3} - C = C^{1}H^{3}$	Methyl	
$C^{1}H^{3} - H^2 = C^{1}H^{1}$	Formyl	Formic acid
$C^{1}H^{1} - C = H^{1}$	Hydrogen	

Commencing with a known radical of very complex constitution, myricyl = $C^{30}H^{61}$, which is equal to 30 atoms of Vinyl, plus 1 atom of hydrogen = $CH^2 \times 30 + H^1$, the Table shows the entire range of radicals which would be produced from the original complex radical by the alternate abstraction of H^2 and C^1 until the components of the radical were exhausted. I have affixed the names of such existing compounds as agree with the successive stages of this reduction, as far as I know them. The list could probably be completed by a careful examination of known organic compounds. As it is, we perceive that this purely theoretical abstract accords wonderfully well with the known products of experimental investigation. The radicals are basic and acid alternately. Out of 30 acid radicals which would complete the list, certainly not less than 23 are known. The existence of the series of basic radicals is not so evident, but the bases have not been so carefully looked for as the acids. Near the lower end of the Table the series is complete, and in respect to these lower members, the evidence is also conclusive, that the acid and basic radicals can be experimentally procured from the radicals next above them, by the abstraction of C^1 or H^2. It would be rash to declare that this is the case throughout the series, but as it has been proved to be true in regard to myricyl, to ceryl, and to cetyl, as well as to the lower members, it is probably true of the whole.

It would, perhaps, be possible to arrange all the known compound radicals in a few such Tables as the foregoing, and thus exhibit their mutual relationship, distinguish the members that are known, and mark the places of those that are unknown. Schedules of this sort would be as useful to a chemical investigator as charts are to a navigator.

Some of the direct uses of this Table may be briefly noticed:

It shows the *principle* upon which any basic radical can be reduced to the acid radical next below it on the list, namely, by the abstraction of H^2; and also upon which every acid radical can be reduced to the basic radical next below it, namely, by the abstraction of C^1. Of course, in another series of radicals having a different progression, the rate of abstraction of C and H would be different.

The discrimination of the radicals is sufficiently clear to render it unnecessary for chemists to confound with one another, as they now frequently do, the basic and acid radicals that are closely related; such as propionyl = C^3H^5 and propyl = C^3H^7; butyryl = C^4H^7 and butyl = C^4H^9; caproyl = C^6H^{11} and hexyl = C^6H^{13}; capryl – C^8H^{15} and octyl = C^8H^{17}, &c. If we adopt radicals, we should treat them fairly, and not call some of them by names that have been allotted to others.

The Table supplies short answers to several questions that are rather puzzling to answer if you object to believe in the existence of compound radicals.

What constitutes an alcohol?

A basic radical + H^1 + O^1. Example: H,C^2H^5O = alcohol.

What constitutes an aldide?

An acid radical + H^1 + O^1. Example: H,C^2H^3O = aldehyd.

What constitutes an ether?

Two basic radicals of the same kind + O^1. Example: C^2H^5,C^2H^5O = ether.

What constitutes a compound ether?

Two basic radicals, one containing CH^2 less than the other + O^1. Example: CH^3,C^2H^5O = ethylate of methyl.

What constitutes a ketone?

An acid radical + a basic radical, containing C^1 less than the acid radical + O^1. Example: CH^3,C^2H^3O = acetone.

What constitutes a hydrated organic acid?

An acid radical + H^1 + O^2 (sometimes O^3 or more). Example: $H,C^2H^3O^2$ = hydrated acetic acid.

What constitutes an anhydride or anhydrous organic acid?

Two acid radicals of the same kind + O^3. Example: $C^2H^3,C^2H^3O^3$ = anhydrous acetic acid.

What constitutes a compound anhydride?

Two different acid radicals + O^3.

What constitutes an organic salt?

One acid radical + one basic radical $+O^2$ or O^3. Example: $C^4H^9, C^2H^3O^2$ = acetate of butyl.

The Model of Water.

Let us return for a moment to the question of the constitution of water. Is it $H+O$, or H^2O, or $\begin{matrix}H\\H\end{matrix}O$, or $H+HO$? See page 31. The evidence that has been adduced in favour of the existence of compound radicals, and explanatory of their modes of combination, is decidedly in favour of the last of these formulæ, $H+HO$. Water differs in no respect, physically, from the gaseous compounds of the fourth group—the ethers or dioxides of radicals. It contains two radicals; its atomic measure is two volumes; its radicals, when isolated, measure each one volume; it contains one volume of oxygen, which adds nothing to its atomic measure. It is readily divisible into hydrogen = H and oxide of hydrogen = HO, both of which enter largely into organic and inorganic salts. In short, it may be taken as the model of a salt consisting of two radicals, with one atom of oxygen. There is, I think, nothing to be said in favour of the other formulæ at all approaching in force to the positive evidence in favour of the formula $H+HO$.

As water is undoubtedly the equivalent of the metallic protoxides, such as anhydrous lime, every argument that can be urged to show that the formula of water is H,HO serves equally to show that the formula of a metallic protoxide is M,MO, and the formulæ of the corresponding hydrate either M,HO, or H,MO. Which of the two latter is the proper formula? is a question that presents some difficulty, not, indeed, as respects the hydrates of the metallic protoxides, but as respects the hydrates of compound radicals. I do not hesitate to write CaHO for hydrate of lime, because I consider hydrogen to be an acid radical against calcium, but if I am to write a formula for alcohol, I hesitate to write C^2H^5,HO, because I consider hydrogen to have, more than any hydro-carbon, the nature of a basic radical, and for that reason I would write the formula H,C^2H^5O. This practice I would generalise, considering H to be an acid radical against any metal, and a basic radical against any hydrocarbon.

The reason that I object to the triangular formulæ, by which Mr. Gerhardt and Professor Williamson indicate the salts that are formed on the model of water, is now evident. I consider all such compounds to be *binary*, and that for *binary compounds*, *ternary formulæ* are improper.

For the same reason, I do not concur in Professor Williamson's opinion, that most salts can be designated by formulæ framed on the model of the formula of water Of the eleven groups of salts described between pages 64 and 68, only the third, fourth, fifth, and tenth groups are, in my opinion, formed on the model of water. The other groups cannot be fairly reduced to that form. Water consists of one oxidised radical and another radical not oxidised; whereas the radicals of the great majority of salts are either not oxidised at all, or are both oxidised. Of the 121 binary compounds, gaseous in two volumes, described in these eleven groups, 35 only are formed on the model of water, and 86 on other models; and even of those which are formed on the model of water, namely, those which contain a single atom of oxygen, the evidence is strongly in favour of the view that their constitution is *binary* $= M + MO$, and not *ternary* $= \begin{matrix}M\\M\end{matrix}O$.

Professor Williamson's views on this subject are explained in his Paper on the Constitution of Salts.[1] It is unnecessary to examine his illustrations in detail, because my general objection applies to the whole of them. In the following examples, the separation of a certain quantity of oxygen from the rest of it is arbitrary and incapable of demonstration, as is also the proposal to consider the compounds ClO, ClO^2, and ClO^3, to be each equivalent to one atom of hydrogen, and the compound SO^2 to be equivalent to H^2, K^2, and HK. The function of oxygen in salts is ignored in these assumptions. That element is never the equivalent of a radical, and all formulæ in which oxidised compounds are represented in the equivalents of single volumes of hydrogen are, in my judgment, constructed on an erroneous principle. Equivalents must be sought for in the radicals alone, independent of their oxygen.

Examples of Professor Williamson's formulæ:—

$\begin{matrix}SO_2\\H_2\end{matrix}O_2$	Sulphuric acid.	$\begin{matrix}(ClO)\\H\end{matrix}O$	Chlorous acid.
$\begin{matrix}SO_2\\K_2\end{matrix}O_2$	Neutral sulphate of potash.	$\begin{matrix}(ClO_2)\\H\end{matrix}O$	Chloric acid.
$\begin{matrix}SO_2\\HK\end{matrix}O_2$	Acid sulphate of potash.	$\begin{matrix}(ClO_3)\\H\end{matrix}O$	Perchloric acid.

According to the radical theory these salts would require the following formulæ:—

HSO^4	Sulphuric acid.	$HClO^2$	Chlorous acid.
KSO^4	Sulphate of potash.	$HClO^3$	Chloric acid.
$KSO^4 + HSO^4$	Bisulphate of potash	$HClO^4$	Perchloric acid.

In all cases of double decomposition, the sulphur, or acid radical, and all the oxygen of these salts go together. There is no evidence to prove that such a division of the oxygen takes place as the triangular formulæ show us.

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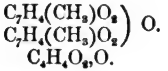
[1] Quarterly Journal of the Chemical Society (1852), iv. 350.

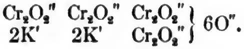
Professor Williamson has recently somewhat changed his views respecting the formulæ of the sulphates, and I shall refer to his latest opinions when I come to discuss the question, whether sulphuric acid is bibasic or monobasic. But, before I quit the "model of water," I must copy a few fashionable formulæ to show to what extent that unfortunate model has been recently tormented, and what strange varieties of fantastic aspect the triangular formulæ, on the model of water, are made to assume.

Gerhardt's "Succinate of methylo-salicyl, or oxide of succinyl and methylo-salicyl."[1]



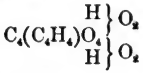
$$\left.\begin{matrix}C_7H_4(CH_3)O_2\\ C_7H_4(CH_3)O_2\end{matrix}\right) O.$$
$$C_4H_4O_2,O.$$

Odling's bichromate of potash:—[2]



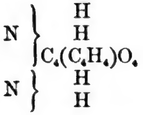
$$\begin{matrix}Cr_2O_2'' \\ 2K'\end{matrix}\quad\begin{matrix}Cr_2O_2'' \\ 2K'\end{matrix}\quad\left.\begin{matrix}Cr_2O_2'' \\ Cr_2O_2''\end{matrix}\right\} 6O''.$$

H. L. Buff's succinic acid:—[3]



$$C_4(C_4H_4)O_4\begin{matrix}\left.H\right\} O_2\\ \left.H\right\} O_2\end{matrix}$$

H. L. Buff's succinamide.—[3]



$$\begin{matrix}N\left\{\begin{matrix}H\\ H\end{matrix}\right.\\ C_4(C_4H_4)O_4\\ N\left\{\begin{matrix}H\\ H\end{matrix}\right.\end{matrix}$$

The dense clouds of philosophical mist which hang over these vast and intricate edifices prevent my seeing their relation to the model of water, and I must refer the reader who wishes to understand them to the descriptions given by their respective architects—descriptions which appear to me to be particularly difficultly intelligible.

The Construction of Formulæ.

It may, perhaps, be not out of place here to make a few remarks respecting *symbols* and *formulæ*. It should be adopted by chemists as an inflexible rule, to use no letters, figures, or other symbols in writing formulæ, but such as can be printed by the types commonly kept in every printing office. There should be no crossed letters, and no brackets, or copulæ that require an unusual description of type.

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[1] Quar. J. Chem. Soc. (1855), vii. 62. [2] Ibid., page 12.

[3] Communicated to the Royal Society by Professor A. W. Hofmann, June 10, 1856. Proceedings Roy. Soc., viii. 195.

The theory of the constitution of the salts which I have advocated in this Essay, namely, that every salt consists of two radicals, simple or compound, oxidised or not oxidised, is one that leads to a simple and regular method of writing formulæ. For example, the benzoate of methyl contains the two radicals benzyl and methyl, combined with two atoms of oxygen. We may consider the two radicals to be each combined with one atom of oxygen, and may represent the salt as a combination of the two oxidised radicals $CH^3O + C^7H^5O$; but, considering that, in cases of double decomposition, the division of the components of this salt seems to take place, not where the sign + is placed, in the above formulæ, but in the following manner: $CH^3 + O,C^7H^5O$, so that all the oxygen appears to go with the acid radical, it is expedient in this and all cases of oxidised salts, to put the whole of the oxygen together at the end of the formula, thus: $CH^3,C^7H^5O^2$. We have here distinctly placed before us the two acting substances of the salt; first, the basic radical, and next, the acid radical, while the subjunctive oxygen is thrown to the end. It is not to be understood, from this proposal, that I wish it to be considered an ascertained fact, that in every salt the oxygen is wholly combined with the acid radical. It may be so, but we have no proof that it is so, and I do not pretend to decide this difficult question. The proposal to indicate all the oxygen in one sum is simply to give regularity to the formula, and, as I shall show presently, to facilitate the construction of a systematic nomenclature.

When there are several radicals, as in all cases of compound salts, they are to be written in a straight line, separating them from one another by a comma, and placing a semicolon before the acid radical. Thus—

$Na, C^5H^9;\ S^2O^3$ . . .	Sulphite of soda and valeryl.
$Ag, C^2H^5,H;\ C^7HO^7$. .	Acid ethylomeconate of silver.

This method of writing formulæ is equally applicable to the salts of inorganic radicals. Thus, the sulphates are MSO^2, the oxalates MCO^2, the carbonates $M,M;\ CO^3$, the nitrates MNO^3, &c.

It does not appear to me to be advisable to adopt abridged symbols for the hydrocarbon radicals, such as Et for ethyl, $\bar{A}$ for acetic acid, and the like. The full symbol for such compounds is only C^mH^n, so that little is gained by abridgment, while we lose the important advantage presented to the eye by the factors which belong to the full symbols. One need not object to Cy instead of CN, because it does not tax the memory, but the symbols of the basic and acid radicals should never be abridged.

Systematic Nomenclature.

I have defined a salt to be a compound of two radicals, simple or compound, with or without oxygen. I proceed to show in what manner such compounds can be provided with simple and accurate names.

The name of each salt is to consist of two words, the first of which is to designate the basic radical, and the second to designate the acid radical, and to specify the number of atoms of oxygen, if any is present. The names of simple radicals are, of course, to be the names of elements or some convenient abridgments of them, such as I have proposed for consideration in the last column of the Table at page 28. The names of compound radicals of the hydrocarbon series, may be such words as ethyl, acetyl, and benzyl. Of these there must be one for every hydrocarbon known to exist. In the selection of such names, it is advisable to avoid those which indicate numbers: trityl, octyl, and the like.

The atoms of oxygen are to be indicated by a change in the termination of the name of the acid radical of each salt. The numerals which I propose for this purpose are as follow:—

1	ate.	6	aze.	11	abate.	16	abaze.
2	ete.	7	eze.	12	abete.	17	abeze.
3	ite.	8	ize.	13	abite.	18	abize.
4	ote.	9	oze.	14	abote.	19	aboze.
5	ute.	10	uze.	15	abute.	20	abuze.

This system is sufficient for all compounds that consist of two radicals in combination with oxygen; but in order to provide names for compounds that contain more than two radicals, and for those which contain no oxygen, it is necessary to provide terminal numerals which are to be used for radicals only, and are not to indicate oxygen. I propose the following:—

1	a, an, or	ane.	11	aban or	abane.
2	e, en,	ene.	12	aben	abene.
3	i, in,	ine.	13	abin	abine.
4	o, on,	one.	14	abon	abone.
5	u, un,	une.	15	abun	abune.
6	ad or	ade.	16	abad	abade.
7	ed	ede.	17	abed	abede.
8	id	ide.	18	abid	abide.
9	od	ode.	19	abod	abode.
10	ud	ude.	20	abud	abude.

It does not appear to be expedient to provide names to indicate numbers above 20, because they would be rarely used, and from want of use, their significance would escape the memory. The system, however, is capable of application to compounds with high numbers of atoms, if it is considered advisable so to apply it. We should have merely to change the consonant of the syllable *ab*, and thus provide a series of numbers for the tens up to 100:—

10 ab.	40 al.	70 ap.
20 af.	50 am.	80 ar.
30 ak.	60 an.	90 av.

Such of the elements as give two radicals already possess characteristic terminations—*ous* and *ic*, which must not be displaced by the numerals. See the table of elements at page 28. I propose to insert the numerals between the root of each name and its terminal *ous* or *ic*. Thus:—

Ferranous = Ferr-an-ous = one ferrous atom.
Ferrinic = Ferr-in-ic = three ferric atoms.

But when only one atom is spoken of, the numeral may in all ordinary cases be omitted, and without causing any doubt to arise, we may say—

Ferrous . . for one ferrous atom.
Ferric . . for one ferric atom.

In some compound words it may be proper, for the sake of brevity, to omit the terminal *ous*, but the same liberty must never be taken with the terminal *ic*, otherwise the distinction between the two kinds of radicals would be lost.

When speaking in a general sense of the non-oxidised salts, I propose to use the termination *ane*, as in the following examples:—

Present Names.		*Proposed Names.*
Fluorides or hydrofluates	=	Fluoranes.
Chlorides or hydrochlorates	=	Chloranes.
Iodides or hydriodates	=	Iodanes.
Bromides or hydrobromates	=	Bromanes.
Sulphides or hydrosulphates	=	Sulphanes.
Phosphides or phosphurets	=	Phosphanes.
Carbides or carburets	=	Carbanes.

But in speaking of individual compounds of this kind, I prefer the use of the termination *a*. Thus:—

Muriatic acid = HCl = Hydra chlora.
Chloride of sodium = $NaCl$ = Natra chlora.
Sulphuret of potassium = KS = Potassa sulpha.
Fluoride of calcium = CaF = Calca fluora.

The following examples show the relation of the names required for oxidised salts to those required for non-oxidised salts:—

Hydrochloric acid = HCl = Hydra chlora.
Hydrated chloric acid = $HClO^3$ = Hydra chlorite.

Chloride of barium = $BaCl$ = Baryta chlora.
Chlorate of barytes = $BaClO^3$ = Baryta chlorite.

Sulphuretted hydrogen = HS = Hydra sulpha.
Hydrated sulphuric acid = HSO^2 = Hydra sulphete.

Sulphuret of iron = FeS = Ferrous sulpha.
Protosulphate of iron = $FeSO^2$ = Ferrous sulphete.

Hydrocyanic acid = HCy = Hydra cyana.
Hydrated cyanic acid = $HCyO$ = Hydra cyanate.

Cyanide of potassium = KCy = Potassa cyana.
Cyanate of potash = $KCyO$ = Potassa cyanate.

To denote WATER OF CRYSTALLIZATION, I propose to abridge the term *aqua* to AQU, and to add the terminals of the oxygen series. Thus:—

Aquate will signify one atom of water.
Aquete ,, two atoms ,,
Aquite ,, three atoms ,,
Aqueze ,, seven atoms ,,
Aquabete ,, twelve atoms ,,

The names which this system provides for the organic compounds of the eleven groups described between pages 64 and 68, are as follows:—

First group, page 64, the names given in the list may remain as they are written, or the terminal *a* may be added to each word, so as to produce Ethyla butyla, &c.

Second group, p. 65, the hydrides:—

H,CH^3 Methyl hydride = Hydra methyla.
H,C^6H^5 Benzine = Hydra phenyla.
H,C^7H^7 Toluine = Hydra toluenyla.

Third group, p. 65. The alcohols and the aldides. In this case we have to indicate one atom of oxygen, for which purpose the acid radical must have the termination *ate*:—

H,CH^3O Methylic alcohol = Hydra methylate.
H,C^2H^3O Aldehyd = Hydra acetylate.
H,C^2H^5O Alcohol = Hydra ethylate.

It is useless to quote more examples, because the names would all be as regular as the formulæ, which cannot be said of the names that appear in page 65.

Fourth group, p. 66. The ethers:—

C^2H^5,C^2H^5O Ether = Ethyla ethylate.
AsC^2H^6,AsC^2H^6O Oxide of cacodyl = Cacodyla cacodylate.

Fifth group, p. 66. Compound ethers and ketones:—

CH^3,C^2H^3O Acetone = Methyla acetylate.
CH^3,C^2H^5O Ethylate of methyl = Methyla ethylate.
C^3H^7,C^4H^7O Butyrone = Propyla butyrylate.

The third, fourth, and fifth groups are named in a similar manner, because their constitution is similar—

Alcohol = $H,\ C^2H^5O$ = Hydra ethylate.
Ether = C^2H^5,C^2H^5O = Ethyla ethylate.
Ethylate of methyl = $CH^3,\ C^2H^5O$ = Methyla ethylate.

These evidently all belong to the class of ethylates, and differ from one another only in their basic radical. The non-volatile substance called potassium alcohol, belongs to the same class, K,C^2H^5O = potassa ethylate.

The prevalent theory of chemistry, and the prevalent prejudices of chemists, are opposed to the adoption of salts which contain only a single atom of oxygen for division between "the base" and "the acid," but such salts nevertheless exist in abundance, and must eventually be generally recognized. These, indeed, are the true salts on the "model of water." Attempts to graft on this model salts that have more than two radicals, or more than one atom of oxygen, are mere delusions.

The ketones described at page 77 belong to this order of salts, and must be named accordingly:—

Acetone $C\ H^3,C^2H^3O$ = Methyla acetylate.
Propione C^2H^5,C^3H^5O = Ethyla propionylate.
Butyrone C^3H^7,C^4H^7O = Propyla butyrylate.
Valerone C^4H^9,C^5H^9O = Butyla valerylate.
Benzone C^6H^5,C^7H^5O = Phenyla benzylate.
Campholene $C^9H^{17},C^{10}H^{17}O$ = Pelargyla camphylate.
Margarone $C^{16}H^{33},C^{17}H^{33}O$ = Cetyla margarylate.
H. C^4H^9,C^2H^3O = Butyla acetylate.

Sixth group, p. 66. Hydrated organic acids. In this group, two atoms of oxygen have to be indicated; which requires the terminal *ete*:—

H,CHO^2 Hydrated formic acid = Hydra formylete.
$H,C^2H^3O^2$ Hydrated acetic acid = Hydra acetylete.
$H,C^7H^5O^2$ Hydrated benzoic acid = Hydra benzylete.

When a hydrated acid becomes a salt, the basic hydrogen is replaced by a basic radical, the name of which takes the place of the word hydra, while the name which indicates the acid part of the salt, and enumerates the oxygen, remains unchanged, as is shown by the next group.

Seventh group, p. 66. Organic salts, in which both of the radicals are compound, and in which there are two atoms of oxygen:—

CH^3,CHO^2 Methyl formiate = Methyla formylete.
$CH^3,C^2H^3O^2$ Methyl acetate = Methyla acetylete.
$CH^3,C^7H^5O^2$ Methyl benzoate = Methyla benzylete.
$CH^3,C^2H^5O^2$ Methylal = Methyla ethylete.

Eighth group, p. 67. Nitrites:—

C^6H^5,NO^2 Nitrobenzid, or nitrite of phenyl = Phenyla nitrete.

Ninth group, p. 67. Haloids:—

C^2H^3,Cl Chloride of acetyl = Acetyla chlora.
CH^3,Cy Cyanide of methyl = Methyla cyana.

Tenth group, p. 68. Oxychlorides:—

C^7H^5,ClO Chloride of benzoile = Benzyla chlorate.
C^2H^3,ClO Oxychloride of acetyl = Acetyla chlorate.

Eleventh group, p. 68. Miscellaneous compounds, containing three atoms of oxygen. The acid radical requires the terminal *ite*, which signifies three atoms of oxygen:—

$C^2H^3,C^2H^3O^3$ Anhydrous acetic acid = Acetyla acetylite.
$C^4H^7,C^4H^7O^3$ Anhydrous butyric acid = Butyryla butyrylite.

The nature of these anhydrous acids will be discussed under the head of "ANHYDRIDES."

$C^2H^5,C^2H^5;\ CO^3$ Carbonate of ethyl = Ethylene carbite. The termination *ene*, in the word ethylene, shows the salt to be bibasic.

$C^2H^5,C^2H^5;\ S^2O^3$ Sulphite of ethyl = Ethylene sulphenite. In the last word the syllable *en* indicates two atoms of sulphur, and the syllable *ite* three atoms of oxygen.

CH^3,NO^3 Nitrate of methyl = Methyla nitrite.

Examples of the application of this nomenclature to other more complex substances than those named in the above groups, will be given when the formulæ of these compounds are explained.

In the designation of double salts, I propose to express the phrase "*combined with*" by the Latin word *cum*.

The Doctrine of Chemical Types and Substitutions.

To illustrate the subject of TYPES and SUBSTITUTIONS, I take the example that was first used by Dumas in developing his theory, and afterwards by Berzelius in his critical condemnation of that theory. Here is the account given by Berzelius:—

"To give an idea," says he,[1] "of the views of atomic composition which arise from the theory of chemical types, I will quote an example given by Dumas of the chemical type to which the oil of bitter almonds belongs, represented by the chemical formulæ required by this theory, in which the elements that play the same part are placed vertically the one above the other—

1. Oil of bitter almonds . . . . . $C^{14}\ H^{6}\ O^{2}$
2. Binacichloride (chloride) of benzoyle $C^{14}\left\{\begin{matrix}H^{5}\\Cl\end{matrix}\right\}O^{2}$
3. Benzoic acid . . . . $C^{14}\left\{\begin{matrix}H^{5}\\O\end{matrix}\right\}O^{2}$
4. Binacisulphuret (sulphuret) of benzoyle $C^{14}\left\{\begin{matrix}H^{5}\\S\end{matrix}\right\}O^{2}$
5. (Benzoate of amidogen) benzamide $C^{14}\left\{\begin{matrix}H^{5}\\NH^{2}\end{matrix}\right\}O^{2}$

"Amongst these very different compounds, the rational composition of which is expressed by the names here employed, it is not only presumed that chlorine, sulphur, and oxygen play the same part, but that this is likewise the case with hydrogen; they are therefore supposed to occupy the same position as one equivalent of hydrogen in the oil of bitter almonds, or in their prototype. The fifth example presents the most remarkable circumstance, that the same space which in oil of bitter almonds is occupied by 1 equivalent of hydrogen, suffices not only for 2 equivalents of hydrogen, but in addition for 1 equivalent of nitrogen. The mechanical impossibility is no obstacle to this theory, and the supporters of metalepsy find no difficulty in replacing an equivalent of hydrogen by 4 atoms or equivalents of oxygen and 1 equivalent of nitrogen, or by 2 atoms of oxygen and 1 atom of sulphur."

It is a proof of the soundness of the theory which I am advocating, that it is able to clear up readily a point which for years served as basis for a controversy between two such chemists as Berzelius and Dumas. Before I proceed to write the formulæ for these compounds, according to my system, I must point out that in the formula, No. 3, benzoic acid, there is a fallacy which I must let Dumas himself explain. He says:

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[1] Taylor's Scientific Memoirs (1846), vol. iv. p. 670.

"The oil of bitter almonds $C^{28}H^{10}O + H^2$, when exposed to air loses H^2, and ought in consequence to gain O, and be converted into benzoic acid $C^{28}H^{10}O^3$, which actually occurs."—*Traité de Chimie*, 1847, I. 76.

"The essence of bitter almonds can be transformed into benzoic acid by the action of oxygen or of air, or the effect of any oxidising cause whatever. The action takes place at the ordinary temperature, and is rapid in sunshine. The conversion is complete, and immediately produces *hydrated benzoic acid*, containing precisely the quantity of water which it retains after sublimation."—*Idem*, p. 144.

These extracts show that the formula for No. 3 requires an atom of water to be added, making it, according to Dumas's numbers, $C^{28}H^{10}O^4 + H^2$, or according to Berzelius's numbers—

$$C^{14}\left\{\begin{matrix} H^5 \\ HO^2 \end{matrix}\right\} O^2$$

According to my notation these compounds are constituted as follows:—

1. Oil of bitter almonds . .	$H, \; C^7H^5O$.
2. Chloride of benzoyle . .	$Cl, \; C^7H^5O$.
3. Benzoic acid	$HO, \; C^7H^5O$.
4. Sulphuret of benzoyle .	$S, \; C^7H^5O$.
5. Benzamide	NH^2, C^7H^5O.

Looking from this point of view at the explanations given by both parties, it would appear that Dumas was evidently right in supposing that the Cl,HO,S, and NH^2, were respectively substituted for AN *atom* of hydrogen, and that Berzelius was equally right in supposing that this series of compounds contained, all through, the compound C^7H^5O. But, on the other hand, Dumas was wrong in supposing that the atom of hydrogen which he replaced was *any one atom taken indifferently* from the mass of atoms of hydrogen contained in the oil of bitter almonds. He failed to perceive that the hydrogen which he replaced was a *radical*, equal in chemical power, not to each of the other atoms of hydrogen present in the compound, but to all the rest of the hydrogen and all the carbon taken together; for the radical benzyl = C^7H^5 is but one molecule, the equivalent of one volume of hydrogen, and this molecule remained undecomposed while the compound underwent all the transformations which formed the basis of the great controversy between these chemists. Berzelius failed equally to notice this peculiarity, so strikingly confirmative of his hypothesis of compound radicals. He was also wrong in urging it as a mechanical impossibility that an atom of amidogen should replace an atom of hydrogen; for, as far as analogy can be trusted, the volume of NH^2 in gaseous combination is exactly the same as that of H; and it has been proved by evidence in the preceding pages, that there is no mechanical hindrance to the replacement of a single volume of hydrogen by a single volume of a compound of several atoms, since it is proved that a heavy complex hydrocarbon, such as lauryl = $C^{12}H^{23}$, whose elements probably *measure* 35 times, and certainly *weigh* 167 times, as much as hydrogen, can be obtained in the volume of a single atom of hydrogen; for the laurate of ethyl = $C^{2}H^{5},C^{12}H^{23}O^{2}$, the atomic weight of which is 228, has a specific gravity of 114, and an atomic measure of two volumes, which is equal to that of its two radicals, the oxygen, as usual, measuring nothing.

The five compounds which form the subject of the foregoing criticism, would, in accordance with the radical theory, be formulated and named as follows:—

1. $H, \; C^{7}H^{5}O$ = Hydra benzylate.
2. $C^{7}H^{5},ClO$ = Benzyla chlorate.
3. $H, \; C^{7}H^{5}O^{2}$ = Hydra benzylete.
4. $C^{7}H^{5}SO$ = Benzyla sulphate.
5. $NH^{2},C^{7}H^{5}O$ = Amida benzylate.

Compound Chlorine Radicals.

In the case of this TYPE of oil of bitter almonds, the SUBSTITUTION that occurs affects only the different radicals with which the oxidised benzyl successively combines. Hydrogen gives place to chlorine, that to oxidised hydrogen, that to sulphur, and that to amidogen; but all through the series of transformations the benzyl remains unchanged.

There is, however, a species of substitution of an entirely different character from the former, and which has not always been so clearly distinguished from it by chemical writers as it ought to have been. I allude to that species where hydrocarbons, such as methyl and ethyl, are so acted upon by chlorine, bromine, and iodine, as to lose their original composition, and to produce new compounds, which still act as radicals, but are constituted as follows:—

From Methyl = CH^{3}.	From Ethyl = $C^{2}H^{5}$.
$CH^{2}Cl$.	$C^{2}H^{4}Cl$.
$CHCl^{2}$.	$C^{2}H^{3}Cl^{2}$.
CCl^{3}.	$C^{2}H^{2}Cl^{3}$.
	$C^{2}HCl^{4}$.
	$C^{2}Cl^{5}$.

In these compounds the energetic acid radical chlorine acts the part of the basic radical hydrogen. Bromine and iodine act to some extent in the same way. The above complex compounds form each only a single radical, and it will be seen, on consulting the Table of Gases, under "Chlorine Compounds" at page 54, that each chlorine radical, however heavy, forms only a single volume of gas, and that when they form gaseous salts by combining with other radicals, the salts, whether oxidised or not oxidised, produce only two volumes of gas; the chlorine radicals thus agreeing in their general characteristics with the hydrogen radicals from which they are derived, only diminishing progressively in basic intensity as the proportion of chlorine increases.

In subsequent sections, I shall show that sulphur, nitrogen, and certain metals are also subject to act vicariously for hydrogen in compound radicals.

In regard to the nomenclature of such radicals, I venture to propose that each should retain the name of its original hydrocarbon, with a prefix to denote the number of atoms of chlorine, or other element, introduced into it by substitution. This will show the relationship of the *derived* to the *original* radical, and also the extent of the change effected. Examples:—

Ethyl Series.

C^2H^4Cl = Chloric-ethyl.
$C^2H^3Cl^2$ = Chlorenic-ethyl.
$C^2H^2Cl^3$ = Chlorinic-ethyl.
$C^2H\,Cl^4$ = Chloronic-ethyl.
C^2Cl^5 = Chlorunic-ethyl.

Methyl Series.

CH^2Cl = Chloric-methyl.
$CH\,Cl^2$ = Chlorenic-methyl.
CCl^3 = Chlorinic-methyl.

Acetyl Series.

C^2Cl^3 = Chlorinic-acetyl.

When nitrogen is an element in a compound radical, I propose to indicate it by the symbol Z and the syllable Zot, derived from Azote, excepting in the case of CN.

Inquiry into the Causes which modify the Atomic Measure of Compound Gases.

It is a fundamental principle of the radical theory that a gaseous element has an atomic measure of one volume. Accordingly, one volume is the measure allotted in the Table of Gases to one atom of oxygen, hydrogen, nitrogen, and chlorine.

A second axiom of the radical theory is, that every compound radical which acts as the equivalent of an atom of hydrogen or of chlorine, measures, in the gaseous state, like its equivalents, one volume. In all cases, where these compound radicals have been isolated and weighed, they have been found to agree with this axiom. Thus one volume has been found by experiment to be the atomic measure of the following compounds:—

$C\,H$	Formyl.	C^4H^9	Butyl.	C^8H^{12}	Cedrene.
$C\,H^2$	Vinyl.	C^5H^7	Camphogene.	$C^{10}H^{16}$	Petrolene.
$C\,H^3$	Methyl.	C^5H^9	Menthene.	$C^{10}H^{21}$	Paraffine.
C^2H^5	Ethyl.	C^5H^{11}	Amyl.	AsC^2H^6	Cacodyl.
C^3H^5	Acryl.	C^6H^{13}	Hexyl.	CN	Cyanogen.

In the third place, compounds of two radicals, whether the radicals are simple or compound, oxidised or not oxidised, are assumed to form two volumes of vapour, because their two radicals *combine without condensation.* The groups of compounds between pages 64 and 68, show 121 proofs of the correctness of this assumption, to which I may now add the following compounds, which are equally regular, and were only excluded from the former groups because they are not hydrocarbons, and it appeared to be desirable to keep the argument respecting the hydrocarbons free from extraneous considerations. The following compounds form two volumes of gas:—

HHO	Water.	HCy	Cyanhydric acid.
HCl	Chlorhydric acid.	CyBr	Bromide of cyanogen.
HBr	Bromhydric acid.	CyCl	Chloride of cyanogen.
HI	Iodhydric acid.	C^6H^5,Cy	Cyanide of phenyl.

So far the atomic measures, both of elements and compounds, are all regular. There is one volume for an atom of a radical, and two volumes for an atom of a compound of two radicals. But the above compounds amount to less than half the number that are contained in the Table of Gases, and we have now to consider the compounds whose measures are apparently irregular.

The fact has already been pointed out, that oxygen, which, in the free state, measures one volume, measures nothing when in combination with two radicals, but serves only to increase the *weight* of the compounds into which it enters. I cannot account for that fact, and will not dwell upon it, but proceed to the consideration of the properties of other elements.

CARBON.—Carbon, occurring as an acid radical, in combination with other radicals measures nothing. The oxalate of amyl = $C^5H^{11}O,CO$, and the oxalate of ethyl = C^2H^5O,CO, each measure one volume, which is due to the amyl and methyl they contain. The double oxalate of ethyl and methyl = CH^3,C^2H^5; C^2O^4 measures two volumes, because it contains two basic radicals. The carbonate of ethyl = C^2H^5,C^2H^5; CO^3 also measures two volumes, and for the same reason. In all these cases the radical carbon and the oxygen measure nothing. On the other hand, carbonic oxide = CO, and carbonic acid = CO^2, when uncombined with other radicals, both measure two volumes. In the case of CO^2 this is the measure of the oxygen, but in the case of CO, the volume is twice the measure of the oxygen. These measures are therefore irregular. In combination with other radicals all combinations of C with O measure nothing.

The reader, in examining the facts and arguments of this section, will do well to bear in mind the particulars of these irregular and exceptional compounds, which occur, not only among the oxides of carbon, but also among the oxides of nitrogen, sulphur, and chlorine. It will be seen, that the most irregular gases are among the best known inorganic compounds, and that the great multitude of organic vapours present scarcely any irregularities.

VINYL.—Olefiant gas, or vinyl = CH^2 (see page 73) has an atomic measure of one volume.

The facts with which my arguments are interspersed, between pages 64 and 81, show the important relationship that exists between vinyl and an extensive series of volatile radicals. The basic radicals are composed *as if*—I am now entering upon the boundary of conjecture, *as if*—each was composed of a multiple number of atoms of vinyl plus a single atom of hydrogen = H, and the acid radicals appear *as if* they contained a multiple number of atoms of vinyl, plus a single atom of formyl = CH. Now these compound radicals, basic and acid, from the simplest to the most complex, all measure one volume, which is precisely the same measure as that of the single atoms of H and of CH. Then, as we have found that carbon measures nothing when in combination, with the exception of CO and CO^2, it follows that the atom of carbon in the compound CH, may measure nothing, and that the single atom of hydrogen which is present alike in the basic and acid radicals, over and above the quantity necessary to the constitution of the multiples of vinyl, is *the only thing which* MEASURES *in the state of gas.* All the vinyl, however great the quantity, from one atom up to thirty atoms, measures nothing, and the odd atom of carbon in the acid radicals also measures nothing. The vinyl and the carbon increase the WEIGHT of the gas, but the MEASURE is that of the single atom of hydrogen. This atom of hydrogen is essential to the existence of every member of the great class of radicals exhibited in the Table at page 79, and probably to the existence of most of the basic and acid radicals that are volatile; and when it is not essential to their existence its absence appears to be marked by some peculiar characteristic.

The following are examples of such a peculiarity:—

$C^2H^5,C^2H^2O^2$ = Succinate of ethyl = Ethyla succinylete.
$C\,H^3,C^2H^2O^2$ = Succinate of methyl = Methyla succinylete.

These two salts have an atomic measure of only one volume, which is the measure of their basic radicals; the succinyl, which is probably constituted thus: CH^2+C, for want of the odd atom of hydrogen measures nothing. For the same reason, the following salt, which contains 3 radicals, measures only two volumes.

H,H; $C^7H^4O^2$ = Salicylous acid = Hydren salicylete.

Regnault's bibromide of ethylene = C^2H^4,Br^2, with the atomic weight of 188, and the specific gravity of 94, is quite irregular, showing two volumes and three radicals. But if we divide this compound by 2, and consider it as bromide of vinyl = CH^2,Br, the atomic weight and specific gravity are both 94, and the measure is one volume, which, on the assumption that vinyl has no measure in combination is correct, one volume being the measure of the bromine.

Unfortunately we know yet too little of the constitution of compounds of this kind, to be able to settle difficult cases so readily; and as an example of the uncertainty that attends such arrangements of atoms, I may mention that this compound is susceptible of even a third grouping, which has a great appearance of truth. If we represent it by the formula $C^2(H^4Br), Br$, it seems to be a bromide of a variety of ethyl in which one atom of hydrogen has been replaced by one atom of bromine, similar to the chlorine compound that I have described at page 93. Such a compound should weigh 188, and measure two volumes, and have a specific gravity of 94, in all which respects the gas and the formula agree.

Upon the whole it seems probable that no hydrocarbon radical measures anything in its gaseous salts, unless it contains an odd atom of hydrogen, or of chlorine (or other element) in substitution for hydrogen. The number of apparent radicals that contain an even number of atoms of hydrogen is very small, and may possibly be diminished when the compounds are better understood.

The expression of these decided opinions respecting the odd atom of hydrogen which characterises both the basic and acid radicals of the hydrocarbon series, will, no doubt, lead many persons to inquire, what I think of Laurent and Gerhardt's LAW OF EVEN NUMBERS OF ATOMS? According to that law, nearly all organic compounds contain an even number of atoms of carbon, and an even number of atoms of hydrogen. The law requires the atomic weight of every compound to be so established, that the vapour of its atom may occupy four volumes. This law is explained more fully in *Gmelin's Chemistry*, vol. vii., p. 6, and in *Laurent's Chemical Method*, pages 46 to 129.

My opinion of the law is, that it is quite true and utterly useless. The reason is, that the compounds to which it refers are all complete in two volumes. The atoms included in that measure must, in every instance, either be even or odd. The law requires the measure to be taken at four volumes. If the original numbers are even, multiplication by two (to make two volumes into four) LEAVES *them even*. If the numbers are odd, multiplication by two MAKES *them even*. The law therefore is a mere artifice of arithmetic, and instead of holding a place in our systems of chemistry, it ought to be transferred to the pages of Hutton's Mathematical Recreations. *

SULPHUR.—An atom of sulphur in the state of vapour measures one-sixth part of a volume; but this measure disappears when the sulphur is in combination with other radicals. The sulphur then adds to the weight of the compound but not to the gaseous volume. When one or more atoms of sulphur are combined with a single radical, the

* In Hutton's mathematical recreations the fact that C's are generally remain odd, won [illegible] be

compound measures one volume; when they are combined with two radicals, the compound measures two volumes. The presence of oxygen adds nothing to the measure.

Examples:—

		a. Compounds forming One Volume of Gas.		*Proposed Names.*
$C H^3 S$	=	Methyl, sulphide	=	Methyla sulpha.
$C H^3 S^2$	=	Methyl, bisulphide	=	Methyla sulphene.
$C H^3 SO^2$	=	Methyl, sulphate	=	Methyla sulphete.
$C^2H^5 S$	=	Ethyl, sulphide	=	Ethyla sulpha.
$C^2H^5 S^2$	=	Ethyl, bisulphide	=	Ethyla sulphene.
$C^5H^{11}S$	=	Amyl, sulphide	=	Amyla sulpha.
AsC^2H^6,S	=	Cacodyl, sulphide	=	Cacodyla sulpha.
HS	=	Hydrosulphuric acid	=	Hydra sulpha.
ClS	=	Chloride of sulphur	=	Chlora sulpha.
ClS^2	=	Dichloride of sulphur	=	Chlora sulphene.
$ClSO$	=	Chlorosulphuric acid	=	Chlora sulphate.

		b. Compounds producing Two Volumes of Gas.		*Proposed Names.*
$H,C^2H^5;\ S^2$	=	Mercaptan	=	Hydra ethyla sulphene.
$H,C^5H^{11};\ S^2$	=	Hydrosulphide of amyl	=	Hydra amyla sulphene.
$C^2H^5,C^2H^5;\ S^2O^3$	=	Sulphite of ethyl	=	Ethylene sulphenite.
$H,C^4H^9;\ S^2$	=	Butylic mercaptan	=	Hydra butyla sulphene.
$CCl^3,SO + ClSO$	=	Sulphite of perchloride of carbon	=	Chlorinic methyla sulphate cum chlora sulphate.

SO = the atom of sulphurous acid gas, measures one volume, although S and O in combination with other elements measure nothing. S,SO^3 = anhydrous sulphuric acid, and HSO^4 = hydrated sulphuric acid, both measure two volumes. The volume of these three compounds when uncombined with other radicals, is therefore quite regular; that is to say, the sulphur measures as a radical, and the oxygen has no measure. SO^2 and SO^3 in combination with radicals, measure nothing.

The compound CS^4, commonly called bisulphide of carbon, but which I propose to call xanthyl, has an atomic measure of two volumes; but when it is in combination, it measures nothing. The following three gaseous salts contain each two compound organic radicals, besides oxygen and xanthyl, and each measures only two volumes:—

$CH^3,CH^3;\ CS^4O$ = Methylene xanthylate.
$CH^3,CH^3;\ CS^4S^2$ = Methylene xanthyla sulphene.
$CH^3,C^2H^5;\ CS^4O$ = Methyla ethyla xanthylate.

In these cases the basic radicals retain their full measure: the carbon, sulphur, and oxygen, measure nothing.

NITROGEN.—The specific gravity of nitrogen gas is 14, which being taken as its atomic weight, its atomic measure is one volume.

When it combines with oxygen it forms three gases which measure two volumes each:—

Protoxide of nitrogen = N,NO.
Deutoxide of nitrogen = NO.
Peroxide of nitrogen = NOO.

The first of these three compounds is regular, namely, the measure of the two radicals is retained, and that of the oxygen is lost. But the last two have twice the measure that they would have, if the oxygen, according to its usual practice on entering into combination, disappeared. The irregularity of these two compounds is similar to that which characterises CO and COO. When in combination with other radicals, NO and NOO measure one volume, the oxygen disappearing.

There are two other compounds of nitrogen and oxygen, the measures of which have not been determined. These are anhydrous nitrous acid = N,NO^3, and anhydrous nitric acid = N,NO^5. We have, however, the atomic measure of one of the hydrates of nitric acid = $2HNO^3 + 3HHO$. The measure is ten volumes, which is regular; namely, four volumes for the two atoms of HNO^3, and six volumes for the three atoms of water. The nine atoms of oxygen present in this compound measure nothing.

AMMONIA.—Ammonia contains $N + H^3$, which weigh 17; its specific gravity is 8·5, and its atomic measure is consequently two volumes. It is, in my opinion, not a radical, but a salt; the components of which are $H + NH^2$. The compound NH^2 is a radical. It has been named amidogen, or briefly amid. It cannot be prepared in a free state, but its progress can be traced through a multitude of salts, in which it evidently acts as a basic radical. I assume, therefore, that amid is a radical, and that its atomic measure is one volume.

The compound NH^2,H = amida hydra, or the hydride of amid, commonly called ammonia, is in that case a salt, containing two radicals, and having therefore an atomic measure of two volumes.

The radical NH^2 = amid, and the salt NH^2,H = ammonia, are subject to have part, or the whole, of their hydrogen replaced by compound radicals. The following are examples:—

NH,C^2H^3; H = Acetylamine.
NH,C^2H^5; H = Ethylamine.
NH,CH^3; H = Methylamine.
NH,C^6H^5; H = Phenylamine (Aniline).
NH,C^5H^9; H = Piperidine.
NCH^3,C^5H^9; H = Methylopiperidine.
NC^2H^5,C^5H^9; H = Ethylopiperidine.

These salts may all be considered as the equivalents of ammonia, and they each possess an atomic measure of two volumes.

A great number of compounds of this description are formed by the combination of nitrogen with non-volatile radicals. My illustrations are here restricted to compounds that form gases.

It is possible that the compound called *nicotine* = NC^5H^7, the atomic measure of which is one volume, may be an amid = NH,C^5H^6.

Compounds of Ammonia.—Ammonia, as I have said, is a salt and not a radical. When it goes into combination, it does not combine as a basic radical with an acid radical to produce a simple salt, but it combines as a salt with another salt, to produce a compound salt. The result is, that the volatile double salts of ammonia form gases whose atomic measure is *four volumes*, because each double salt contains *four radicals*. The only exceptions to this measure are where the radicals lose their measure in combination, as is the case with sulphur.

Examples:—

$H,NH^2 + HCl$	Hydrochlorate of ammonia.
$H,NH^2 + HCy$	Hydrocyanate of ammonia.
$H,NH^2 + HTe$	Hydrotellurate of ammonia.
$H,NH^2 + HS + HS$ . . .	Bi-hydrosulphate of ammonia.

In the last case, the amid and the three atoms of hydrogen make up the four volumes, the sulphur having no measure. In the third example we find that hydrotelluric acid, which alone measures only one volume, produces two volumes when in combination. The neutral hydrosulphate of ammonia = $H,NH^2 + HS$, has an atomic measure of three volumes, because the sulphur measures nothing, and the measure is made up of one volume of amidogen and two volumes of hydrogen.

The study of the constitution and nomenclature of the ammoniacal salts will be resumed in a subsequent section.

When nitrogen combines with carbon to form the compound radical cyanogen = CN, the product measures one volume, the nitrogen retaining its measure, and the carbon, as usual, losing it.

In the cyanides and cyanates the atomic measure of the cyanogen is retained; but the following examples show that this is not the case with the cyanurates:—

Gaseous chloride of cyanogen	$ClCy$	= 2 volumes.
Solid chloride of cyanogen	$ClCy$	= $\frac{4}{6}$ volume.
Cyanate of ethyl	C^2H^5,CyO	= 2 volumes.
Cyanurate of ethyl	C^2H^5,CyO	= $\frac{4}{6}$ volume.
Cyanide of methyl	$C\,H^3,Cy$	= 2 volumes.
Cyanurate of methyl	$C\,H^3,CyO$	= $\frac{4}{6}$ volume.

These relations lead to the inference that cyanogen exists in the cyanates and the cyanurates under different physical conditions, and that, in the latter, it possesses the properties, common to several elements, of having in combination an atomic measure of $\frac{1}{6}$ volume, with the power of condensing the measure of all radicals with which it combines from one volume each to half a volume; whence it follows that, as is shown in the above table, its salts have a common measure of $\frac{4}{6}$ volume. It is probable that cyanogen exists in this condensed condition in its fulminating salts, but their explosive decomposition by heat renders the determination of their measure impossible. I propose to distinguish, in formulæ and names, the cyanogen of the cyanurates from that of the cyanides and cyanates, by giving to the former the sign Cyl and the name cyanyl. The three gaseous salts referred to above as measuring each $\frac{4}{6}$ volume, will then become:—

$Cl\ \ Cyl$ = Chlora cyanyla.
$C^2H^5,CylO$ = Ethyla cyanylate.
$C\,H^3,CylO$ = Methyla cyanylate.

CHLORINE, BROMINE, IODINE, FLUORINE.—These elements when acting as radicals, and combining with compound organic radicals, or with hydrogen, retain their atomic measure undiminished. See group nine, page 67. But when they become constituents of radicals, acting as substitutes for hydrogen (see page 93), they become subject to the same law as hydrogen, and lose their atomic measure. See the proof of this fact under the head of "Chlorine Compounds" in the Table of Gases, page 54. I will quote a few comparative examples of hydrogen and chlorine radicals:—

Usual Names.

$C^2H^3,Cl\,O$ = Oxychloride of acetyl = 2 volumes.
$C^2Cl^3,Cl\,O$ = Chloraldehyd = 2 volumes.

$H,C^2H^3O^2$ = Acetic acid = 2 volumes.
$H,C^2Cl^3O^2$ = Chloracetic acid = 2 volumes.

H,C^2H^3O = Aldehyd = 2 volumes.
H,C^2Cl^3O = Chloral = 2 volumes.

$C^2H^5,\ \ Cl$ = Chloride of ethyl = 2 volumes.
$C^2H^4Cl\,,Cl$ = Monochlorinated ditto = 2 volumes.
$C^2H^3Cl^2,Cl$ = Bichlorinated ditto = 2 volumes.
$C^2H^2Cl^3,Cl$ = Terchlorinated ditto = 2 volumes.
$C^2H\,Cl^4,Cl$ = Quadrichlorinated ditto = 2 volumes.
$C^2Cl^5\ \ ,Cl$ = Sesquichloride of carbon? = 2 volumes.

CH^3,Cl = Chloride of methyl = 2 volumes.
CCl^3,Cl = Bichloride of carbon = 2 volumes.

H,CH^3 = Marsh gas = 2 volumes.
H,CCl^3 = Chloroform = 2 volumes.

CH^3 = Methyl = 1 volume.
CCl^3 = Sesquichloride of carbon? = 1 volume.
$CHCl^2$ = Perchloride of formyl = 1 volume.
CH^2Cl = Dutch liquid = 1 volume.

CH^2 = Vinyl (olefiant gas) = 1 volume.
CCl^2 = Protochloride of carbon = 1 volume.
CHCl = Chloride of formyl = 1 volume.

Here it is seen, that one, two, three, four, or five volumes of chlorine may, as substitutes for equal volumes of hydrogen, become *part* of a compound radical, which radical measures altogether only one volume; while the same salt which contains that compound radical, may also contain, as a simple radical, chlorine, retaining its full measure of one volume for one atom.

The compounds of chlorine with oxygen present some peculiarities. Hypochlorous acid = Cl,ClO measures two volumes, and is therefore regular, the oxygen measuring nothing. Chloric oxide, or the peroxide of chlorine = ClO^2, also measures two volumes, which is irregular, as it contains only one radical. This irregularity resembles that which occurs with carbonic acid = CO^2, and the peroxide of nitrogen = NO^2. All these compounds become regular when they become part of salts. The volume of the oxygen then disappears. Chlorous acid = $ClClO^3$, apparently forms three volumes of vapour, but the specific gravity of the gas has probably not been correctly determined. Chlorosulphuric acid = ClSO measures one volume; the double salt $CCl^3SO + ClSO$ measures two volumes. Both of these salts are regular, on the supposition that CCl^3 is a compound radical (vicarious methyl), and that S and O measure nothing.

Chlorochromic acid = ClCrO also measures one volume, which seems to intimate that CHROMIUM, like sulphur, measures nothing when in combination with other radicals.

On the other hand, chloro-nitrous gas = ClNO measures two volumes which is regular, because neither nitrogen nor chlorine lose their measure in combination; while here, as in all cases, the volume of the oxygen disappears.

PHOSPHORUS.—The atomic weight of phosphorus is 31, and the specific gravity of its vapour is 62, so that its atomic measure is half a volume. The atom of phosphorus, on combining with other radicals, reduces the measure of the whole of them from a volume each to half a volume, and then adds to the product its own half volume.

Examples :—

H^3P. The measure is 2 volumes = $\frac{3}{2} + \frac{1}{2}$.
Phosphuretted hydrogen = Hydrine phospha.

Cl^3P. The measure is 2 volumes = $\frac{3}{2} + \frac{1}{2}$.
Terchloride of phosphorus = Chlorine phospha.

Cl^5P. The measure is 3 volumes = $\frac{5}{2} + \frac{1}{2}$.
Pentachloride of phosphorus = Chlorune phospha.

Cl^3PO. The measure is 2 volumes = $\frac{3}{2} + \frac{1}{2}$.
Oxychloride of phosphorus = Chlorine phosphate.

C^2H^5,C^2H^5,C^2H^5 ; PO^3. The measure is 2 vols = $\frac{3}{2} + \frac{1}{2}$.

Tribasic phosphite of ethyl = Ethyline phosphite.

This is a remarkable case. The three atoms of ethyl are all reduced from one volume each to half a volume, so that phosphorus has the same power of reduction over compound radicals that it has over elementary radicals. The oxygen as usual disappears.

H^3P,HI. The atomic measure is four volumes. I regard this as a double salt. The measure of H^3P, as shown above, is two volumes = $\frac{3}{2} + \frac{1}{2}$. The measure of HI, as shown at page 59, is two volumes. These two salts combine without farther condensation. Hydriodate of phosphuretted hydrogen = hydrine phospha cum hydra ioda.

H^3P,HBr. Similar to the preceding. The measure is four volumes. Hydrine phospha cum hydra broma.

ARSENIC.—The atom of arsenicum = Asc, atomic weight = 25, measures one-sixth of a volume in the state of gas, for its specific gravity is 150. When arsenic combines with another radical, it causes the atomic measure of that other radical to be reduced from a volume to half a volume = three-sixths of a volume, to which the arsenic adds its one-sixth of a volume, producing in all four-sixths of one volume. The atomic measure of all the following examples is therefore four-sixths of a volume :—

AscCl	Chloride of arsenic	= Arsanic chlora.
AscI	Iodide of arsenic	= Arsanic ioda.
AscH	Arseniuretted hydrogen	= Arsanic hydra.
$AscC^2H^5$	Arsentriethyl	= Ethyla arsanic.

Arsenious acid in the state of gas measures two-sixths of a volume, or only half as much as the other compounds of arsenic. This is easy of explanation. Its formula is Asc,AscO, namely, it contains two arsenic atoms, each measuring one-sixth of a volume, and one atom of oxygen, which measures nothing. The systematic name of Asc,AscO is arsanic arsanicate.

Cacodyl contains one arsanous atom, weighing 75, and two atoms of methyl, weighing in all 105. This compound might be expected to measure $\frac{3}{6} + 2$ volumes; but its measure is exactly one volume. The reason of this is, that this compound is a radical, and has *the measure*, as it is *the equivalent*, of one volume of hydrogen. All the compounds of cacodyl are regular in their atomic measure, even the oxychloride = $6\,[AsC^2H^6,Cl] + [AsC^2H^6]^2O$, which contains six atoms of chloride of cacodyl, with one atom of oxide of cacodyl; for it has the remarkable atomic measure of fourteen volumes, being two volumes for each of the seven regular salts which compose it.

Contrary to the opinion usually entertained by chemists, the action of arsenic in gaseous compounds, whether we refer to the arsanic atom or the arsanous atom, is different from the action of phosphorus. If we adapted another atom of phosphorus = Pc, weighing 10.33, which would be the equivalent of 1 volume of hydrogen, they would be brought into harmony.

Antimony.—We do not know the atomic measure of antimony, because it is not volatile, but we can examine its action upon other radicals, and we then find that the stibanic atom acts precisely in the same manner as the arsanic atom,—its compounds presenting the atomic measure of four-sixths of a volume, exactly as they would do if the measure of the stibanic atom was one-sixth of a volume, and it had the same power that is possessed by the arsanic atom, of reducing the measure of other radicals in combination with it, from a volume to three-sixths of a volume, and then adding to the result its own one-sixth of a volume, making in all four-sixths of a volume. Examples:—

SbcCl = Terchloride of antimony = Stibanic chlora.
SbcH = Antimoniuretted hydrogen = Hydra stibanic.
$SbcC^2H^5$ = Stib-ethyl = Ethyla stibanic.

Bismuth.—The measure and condensing power of the bismanic atom are, apparently, the same as those of the stibanic and arsanic atoms, the measure of the following compound being four-sixths of a volume:

BicCl. Chloride of bismuth = bismanic chlora.

Boron.—Boron is not volatile when isolated. Its atom has, apparently, the same atomic measure and condensing properties as the arsanic atom, namely, it reduces other radicals to three-sixths of a volume, and then adds its own one-sixth of a volume. Hence, all its compounds measure four-sixths of a volume. Examples:—

BCl Chloride of boron = Bora chlora.
BF Fluoride of boron = Bora fluora.
C^2H^5, BO Borate of ethyl = Ethyla borate.
C^5H^{11},BO Borate of amyl = Amyla borate.
$C\,H^3$, BO Borate of methyl = Methyla borate.

SILICON.—The atomic measure of silicon is unknown. When it is in combination, it reduces the measure of the radical it is combined with, from a volume to half a volume, adding nothing for its own volume. The following examples all measure half a volume:—

$SiCl$ = Chloride of silicon = Sila chlora.
SiF = Fluoride of silicon = Sila fluora.
C^2H^5, SiO = Silicate of ethyl = Ethyla silate.
C^5H^{11},SiO = Silicate of amyl = Amyla silate.

There is another gaseous compound containing silicon, the atomic measure of which is one volume and a half. This compound is the chlorosulphide of silicon = Si^3Cl^2S, the atomic weight of which is 109·5, and the specific gravity 73. To account for this singular atomic volume, I imagine that this compound contains ClS, which measures one volume, SiCl, which measures half a volume, and Si^2 which measure nothing, making one volume and a half together.

Carbon, boron, and silicon, all differ from one another in their power of modifying the atomic measure of compound gases.

TIN.—Tin is not volatile, and its volume is unknown. The stanic atom appears to measure nothing in combination, and to have the power to reduce the radical it combines with, from a volume to half a volume, which is the measure of the following compound:

SncCl. Stannic chloride = Stanic chlora.

TITANIUM.—The same as tin. The following salt measures half a volume:

TiCl. Chloride of titanium = Tita chlora.

TELLURIUM.—The atomic measure of tellurium is unknown. It seems, like sulphur, to lose its volume in combination, without altering the volume of the radical with which it combines. The atom of the following gas measures one volume:

HTe. Telluretted hydrogen = Hydra tellura.

But this gas exhibits another character when in combination with ammonia (see page 100).

SELENIUM.—Selenium, like tellurium and sulphur, has no measure when in combination, and it leaves unaltered the radical with which it combines. An atom of each of the following gases measures one volume, so that selenium, like sulphur, retains its volume when combined with oxygen, though it loses it in all other cases.

HSe. Seleniuretted hydrogen = Hydra sela.
SeO. Selenious acid = Selate.

ZINC.—If we may judge from the single gaseous compound of it that is known, zinc acts like sulphur, namely, it loses its measure in combination, without condensing the radical with which it combines. Hence the following gas measures one volume:

ZnC^2H^5. Zinc ethyl = Ethyla zinca.

"The vapour volume of zincethyl," says Frankland,[1] "is highly remarkable, and almost compels us to conclude that the vapour volume of the double atom of zinc is only equal to that of oxygen, instead of corresponding with the volume of hydrogen, in accordance with the generally received supposition. Zincethyl, therefore, appears to belong to the so-called water type, and to consist of two volumes of ethyl and one volume of zinc vapour; the three volumes being condensed to two; for if we were to assume that an equivalent of zinc occupies the same vapour volume as an equivalent of hydrogen, we should then have the anomaly of the combination of equal volumes of two radicals being attended by condensation."

If Dr. Frankland will compare zinc ethyl with sulphide of ethyl, he will perceive that the vapour volume of zincethyl is in no respect more remarkable than that of sulphide of ethyl. In both salts, the ethyl retains its measure of one volume. In both salts, the combined radical,—sulphur in the one and zinc in the other,—loses its volume. It is of no use to trouble ourselves with a suppositious atomic measure of zinc vapour, because we can neither prove nor disprove any possible conjecture respecting it, and therefore can apply the conjecture to no useful end. Our knowledge of the actual atomic measure of the vapour of sulphur is of no service to us in explaining the constitution of the sulphurous gases, because its measure in combination has no relation to its volume in the free state. But on examining the compounds of sulphur and zinc with ethyl, it is easy to see that the ethyl of each retains its measure, while the measure of the sulphur and the zinc are both lost.

The volume of a compound gas has no constant relation to the volumes of its radicals *per se*. It depends upon the measure which the radicals *retain in combination*, and upon the *condensing power* which each can exercise upon the other.

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[1] Proceedings of the Royal Society (1855), VII. 304.

Mercury.—I have assumed that there are two chemical atoms of mercury: the mercurous atom weighing 200, and the mercuric atom weighing 100. The specific gravity of gaseous mercury is 100, which corresponds to the mercuric atom and to the atomic measure of one volume. When the mercuric atom combines with a radical, it loses its own measure, but leaves the measure of the radical with which it combines unchanged. Consequently, the following compounds have all a measure of one volume, which is due to the metalloid:—

HgcCl Mercuric chloride = Mercuric chlora.
HgcBr Mercuric bromide = Mercuric broma.
HgcI Mercuric iodide = Mercuric ioda.

When the mercurous atom goes into combination with a radical, it adds one volume to the measure of the radical. Hence the following compounds measure two volumes:—

HgCl Mercurous chloride = Mercurous chlora.
HgBr Mercurous bromide = Mercurous broma.

The compound of the mercuric atom with sulphur, the mercuric sulphide, or cinnabar, has an atomic measure of one volume and a half. In this case the mercuric atom retains its volume, and the sulphur triples its volume. It is one of the few examples of apparent expansion. The specific gravity is given on the authority of Mitscherlich, but it is possibly incorrect:

HgcS. Mercuric sulphide = Mercuric sulpha.

Summary.—Notwithstanding the differences that exist in the powers of the various elements, and the irregularities that occur in special gases, the causes which modify the atomic measure of compound gases, are neither imperceptible nor incapable of reduction to systematic order. I have attempted to give them a useful arrangement in the Table on the next page.

I have limited this summary to the specification of three peculiarities of each element or radical. First, its atomic measure in the free state, wherever it has been ascertained. Secondly, its measure when in combination with other radicals. Thirdly, the condensing power possessed by one atom of each element or radical, on each volume of every radical with which it combines.

Oxygen, though not a radical, is placed at the head of the list, as a standard of comparison.

Radicals which produce Gases.	Atomic Weight.	Atomic Measure when Isolated.	Atomic Measure in Salts.	Condensing Power of one Atom of the Radical on each Volume of every Radical with which it combines.
Oxygen . . . O	16	1	0	0.
Carbon . . . C	12		0	0.
Sulphur . . . S	16	⅙	0	0.
Selenium . . Se	40		0	0.
Tellurium . . Te	64		0	0.
Zinc . . . . Zn	32.5		0	0.
Chromium . . Cr	27		0	0.
Hydrogen . . H	1	1	1	0.
Chlorine . . . Cl	35.5	1	1	0.
Bromine . . . Br	80	1	1	0.
Iodine . . . I	127	1	1	0.
Fluorine . . . F	19		1	0.
Nitrogen. . . N	14	1	1	0.
Mercury . . . Hgc	100	1	0	0.
— . . . Hg	200	2	1	0.
Phosphorus . . P	31	½	½	1 volume to ½ volume.
Arsenic . . . Asc	25	⅙	⅙	1 volume to ½ volume.
Antimony . . Sbc	43		⅙	1 volume to ½ volume.
Bismuth . . . Bic	71		⅙	1 volume to ½ volume.
Boron . . . B	3.6		⅙	1 volume to ½ volume.
Silicon . . . Si	7.5		0	1 volume to ½ volume.
Titanium. . . Ti	12		0	1 volume to ½ volume.
Tin . . . . . Snc	29.5		0	1 volume to ½ volume.
COMPOUNDS.				
Radicals . . C^nH^{2n+1}		1	1	0.
Radicals . . C^nH^{2n-1}		1	1	0.
Radicals . . C^mH^{2n}			0	0.
Vinyl . . CH^2	14	1	0	0.
Succinyl . . C^2H^2	26		0	0.
Amidogen . NH^2	16		1	0.
Cyanogen Cy = CN	26	1	1	0.
Cyanyl Cyl = CN	26		⅙	1 volume to ½ volume.

Radicals which produce Gases.		Atomic Weight.	Atomic Measure when Isolated.	Atomic Measure in Salts.	Condensing Power of one Atom of the Radical on each Volume of every Radical with which it combines.
EXCEPTIONS AMONG INORGANIC GASES.					
Carbonic Oxide .	CO	28	2	0	0.
Carbonic Acid .	CO^2	44	2	0	0.
Deutoxide of Nitrogen . .	NO	30	2	1	0.
Peroxide of Nitrogen . .	NO^2	46	2	1	0.
Sulphurous Acid	SO	32	1	0	0.
Selenious Acid .	SeO	56	1	0	0.
Sulphuric Acid, Anhydrous	SSO^3	80	2	0	0.
— Hydrated .	HSO^2	49	2	1	0.
Chloric Oxide .	ClO^2	67.5	2	1	0.
Xanthyl . . .	CS^4	76	2	0	0.

A few of the Organic Salts present exceptions to the above-stated general rules, but it is probable that most of them are attributable to our imperfect knowledge of the composition of the substances which exhibit the irregularities. They are as follow:—

ORGANIC GASES WITH IRREGULAR ATOMIC MEASURES.

	Theoretical Atomic Measure.	Experimental Atomic Measure.
1. Benzoile, chlorohydride $= H,C^7H^5;\ Cl^2$	4 volumes.	2 volumes.
2. Ethyl, tribasic formiate $= (C^2H^5)^3;\ CHO^3$	4 volumes.	2 volumes.
3. Ethyl, œnanthylate $= C^2H^5,C^7H^{13}O^2+C^2H^5,C^7H^{13}O$	4 volumes.	2 volumes.
4. Methyl, tribasic formiate $= (CH^3)^3;\ CHO^3$	4 volumes.	3 volumes.
5. Terchlorinated methylic ether $= CCl^3,CCl^3O$	2 volumes.	4 volumes.
6. Terchlorinated methylic sulphide $= CCl^3,S$	1 volume.	2 volumes.

Number 5 in this list would become regular if formulated thus: $CCl^2,Cl+CCl^2,ClO$, where CCl^2 represents bichlorinated vinyl; and, for the same reason, number 6 would be regular if formulated CCl^2,ClS.

METHOD COMMONLY EMPLOYED BY CHEMISTS TO FIND THE SPECIFIC GRAVITY OF COMPOUND GASES.—The usual method of calculating the specific gravities of compound gases, is described by Sir Robert Kane as follows.[1] "The simplicity shown to exist between the volumes of the constituent and compound vapours, enables us very often to calculate beforehand what the specific gravity of a vapour should be, and thus to ascertain how closely the numbers found experimentally approach to absolute correctness. . . . The general rule is to multiply the specific gravities of the simple gases or vapours respectively, by the volumes in which they combine, to add these products together, and then to divide the sum by the number of volumes of the compound gas produced."

To be able to put this rule into practice, we must know the specific gravities of the gases, as commonly expressed in terms referring to the density of air as unity, and we must also know the assumed combining volume of each elementary gas, and the measure of the compound gas.

On the radical theory, we require only the formula of the compound gas, and the data presented in the above Table, to be able to calculate not only the specific gravity of the compound gas, but its atomic measure also, which is a quantity that the ordinary rule requires to be given as one of the data from which to calculate the specific gravity.

Examples:—

HHO = *Water.* Atomic weight $1+1+16=18$. The two atoms of hydrogen measure two volumes in combination, and the oxygen measures nothing. Hence the atomic measure is two volumes, and the specific gravity is $18 \div 2 = 9$. To find the specific gravity in terms referring to air taken at 1·00, the specific gravity 9 must be divided by 14·47.

SncCl = *Chloride of Tin.* Atomic weight $29{\cdot}5 + 35{\cdot}5 = 65$. The atom of tin measures nothing in combination, and it reduces the measure of the chlorine from one volume to half a volume. Hence the atomic measure of the salt is half a volume, and as it requires two atoms of the compound to complete one volume, the specific gravity is $65 \times 2 = 130$.

$C^4H^5,S + HS$. *Mercaptan.* The hydrosulphate of sulphide of ethyl. Atomic weight, $29 + 16 + 1 + 16 = 62$. The atom of ethyl, like all the compound organic radicals, measures one volume in combination. The atom of hydrogen measures one volume. The two atoms of sulphur measure nothing. No condensing power is present. The total measure is consequently two volumes, and the specific gravity is $62 \div 2 = 31$.

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[1] Elements of Chemistry (1849), page 290.

H,C^2H^5O. *Alcohol.* Atomic weight, $1 + 29 + 16 = 46$. The hydrogen and the ethyl measure in combination one volume each, and the oxygen measures nothing. Hence the atomic measure of alcohol is two volumes, and its specific gravity is $46 \div 2 = 23$.

It is unnecessary to quote other examples, because the Table of Gases, and the discussion which I have just concluded, present them in abundance.

In contrast with the simplicity of the mode of calculation afforded by the radical theory, I will quote Poggendorff's account[1] of the gaseous constitution of the last two compounds, the aspect of which shows the difficulties and uncertainties of the ordinary mode of reckoning:—

	Component Volumes in 1 Vol. of Compound.	Condensation.	Atoms in 1 Vol.	Specific Gravity.
Mercaptan	$CH_3S\frac{1}{6}$	25 : 6	$\frac{1}{6}$	2,15822
	$\frac{1}{2}C_2H_5S\frac{1}{6} + \frac{1}{2}HS\frac{1}{6}$	1 : 1		
	$CH_2 + HS\frac{1}{6}$	2 : 1		
Alcohol	$CH_3O\frac{1}{2}$	9 : 2	$\frac{1}{3}$	1,60049
	$\frac{1}{2}C_2H_5O\frac{1}{2} + \frac{1}{2}HO\frac{1}{2}$	1 : 1		
	$CH_2 + HO\frac{1}{2}$	2 : 1		

One of the marvels of modern chemistry is the persistence of its professors in the practice of comparing the specific gravities of gases with that of common air taken as unity. To be consistent, they should adopt the additional absurdity of taking the composition of common air as the standard of the atomic weights. Just look at these two examples of specific gravities! The atomic weight of mercaptan is 62, and its specific gravity is 31; the atomic weight of alcohol is 46, and its specific gravity is 23; but these numbers are too simple to have the proper look of philosophical profundity, so The Authorities of our science fix the specific gravity of mercaptan at 2·15822, and of alcohol at 1·60049—beautiful numbers! which contain the quantity of Egyptian darkness necessary to render them grand and mysterious, and which confer upon the scientific world the remarkable advantages that always flow from the statement of simple facts in terms which no memory can retain.

THE LAWS THAT REGULATE THE ATOMIC MEASURE OF THE VAPOURS OF POLYBASIC ACIDS, AS ENUNCIATED BY PROFESSOR GERHARDT.—Before closing my inquiry into the causes which modify the atomic measure of compound gases, I must consider certain propositions that have been laid down by M. Gerhardt. I copy them from his recently-published *Traité de Chimie Organique*, tome iv. I may premise, that the objects which M. Gerhardt has in view, are to establish certain laws by which monobasic, bibasic, and tribasic acids may be distinguished from one another, and, in particular, to demonstrate that sulphuric acid and oxalic acid are bibasic acids. To this end, he lays down certain absolute laws, and adduces such examples as he considers sufficient to prove their accuracy and universality. I shall quote the laws and proofs, and then examine their trustworthiness.

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[1] Handwörterbuch der Chemie, Band II, pp. 478, 488.

"Considered in the state of vapour and in the same volume, the neutral ethers of bibasic acids contain *twice* the radical of the alcohol, where the neutral ethers of monobasic acids contain only *once* that radical."—Page 653.

1.	2.	3.	4.
$O\left\{\begin{matrix}C^7H^5O\\C^2H^5\end{matrix}\right.$	$O\left\{\begin{matrix}C^2H^3O\\CH^3\end{matrix}\right.$	$O^2\left\{\begin{matrix}SO^2\\(CH^3)^2\end{matrix}\right.$	$O^2\left\{\begin{matrix}C^2O^2\\(C^2H^5)^2\end{matrix}\right.$
2 volumes	2 volumes	2 volumes	2 volumes
Benzoate of Ethyl.	Acetate of Methyl.	Sulphate of Methyl.	Oxalate of Ethyl.

"Considered in the state of vapour and in the same volume, the chlorides of bibasic acids (the dichlorides) contain *twice* the radical chlorine, where the chlorides of monobasic acids contain it only once."—Pages 653 and 724.

5.	6.	7.	8.
Cl,C^7H^5O	Cl,C^2H^3O	Cl^2,SO^2	Cl^2,CO
2 volumes	2 volumes	2 volumes	2 volumes
Chloride of Benzoyle.	Chloride of Acetyle.	Chloride of Sulphuryle.	Chloride of Carbonyle.

"Considered in the state of vapour, and in the same volume, the neutral ethers of tribasic acids contain *three times* the radical of the alcohol, where the neutral ethers of bibasic acids contain that radical only *twice*, and those of monobasic acids contain it only *once*."—Pages 658 and 694.

9.	10.	11.
$O\left\{\begin{matrix}C^2H^5\\C^2H^3O\end{matrix}\right.$	$O^2\left\{\begin{matrix}(C^2H^5)^2\\C^2O^2\end{matrix}\right.$	$O^3\left\{\begin{matrix}(C^2H^5)^3\\Cy^3\end{matrix}\right.$
2 volumes	2 volumes	2 volumes
Acetate of Ethyl.	Oxalate of Ethyl.	Cyanurate of Ethyl.

"Considered in the state of vapour, and in the same volume, the chlorides of tribasic acids (the trichlorides) contain *three times* the radical chlorine, where the chlorides of bibasic acids contain that radical only *twice*, and the chlorides of monobasic acids contain it only *once*."—Pages 658 and 725.

12.	13.	14.	15.
Cl^3,B	Cl^3,P	Cl^3,PO	Cl^3,Cy^3
2 volumes	2 volumes	2 volumes	2 volumes
Chloride of Boron.[1]	Chloride of Phosphorus.	Chloride of Phosphoryle.	Chloride of Cyanuryle."

These laws are evidently founded upon the examples which M. Gerhardt has adduced to support them. According to him, the examples prove that bibasic and tribasic acids affect the atomic measure of compound gases, or gaseous salts, in a manner entirely different from that in which they are affected by monobasic acids; so that, if you examine two volumes of the vapour of a salt, and find therein one, or two, or three basic radicals, the acid is with certainty known to be monobasic, bibasic, or tribasic, according to the number of the basic radicals which your examination discloses in the two volumes of vapour. In the same manner, the examination of two volumes of a gaseous chloride, and the discovery therein of one, or two, or three atoms of chlorine, proves to M. Gerhardt, that the radical with which the chlorine is combined, is that of a monobasic, bibasic, or tribasic acid, according to the number of atoms of chlorine that are discovered to be present in the two volumes of vapour that are submitted to examination.

The examples that I have quoted seem to support these doctrines; for the facts are accurate, and M. Gerhardt's inferences are plausible. But I cannot, upon evidence of this description, and of this limited extent, jump at once, with that chemist, to the conclusion, that, because two volumes of sulphate of methyl contain two atoms of methyl, sulphuric acid is bibasic, or that, because two volumes of oxalate of ethyl contain two atoms of ethyl, oxalic acid is bibasic. True as the facts are, these inferences do not necessarily follow.

Let us check M. Gerhardt's examples by what we have ascertained, in another manner, to be true in regard to the measure of compound gases. Let us see why his formulæ agree in all cases with two volumes of vapour, and yet fail to prove the truth of his propositions.

No. 1. *Benzoate of Ethyl* = $C^2H^5,C^7H^5O^2$. There are two volumes of vapour because there are two radicals.

In this and all the examples the oxygen measures nothing.

No. 2. *Acetate of Methyl* = $CH^3,C^2H^3O^2$. Again, there are two volumes of vapour because there are two radicals.

No. 3. *Sulphate of Methyl* = CH^3,SO^2. M. Gerhardt arbitrarily doubles the atomic weight of sulphur. I reduce it to 16, the usual weight. The salt, according to the corrected formula, CH^3,SO^2, has two radicals, one acid and one basic; but I have shown (page 97) that sulphur, when acting as an acid radical in a gaseous salt, measures nothing. The salt is therefore complete in one volume; and the reason that two volumes of the vapour contain two atoms of methyl, is because two volumes of the vapour contain two complete atoms of the salt. If the weight of one atom of sulphur could be proved to be 32, that is to say, the equivalent of two atoms of hydrogen, then M. Gerhardt would have some ground for his doctrine, but as all attainable evidence proves the atomic weight of sulphur to be 16, or the equivalent of one atom of hydrogen, the examination of this gaseous salt affords no proof that sulphuric acid is bibasic.

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[1] M. Gerhardt's atomic weight of sulphur is twice as much as mine, and that of boron three times as much. The weights of the other elements agree with mine.

No. 4. *Oxalate of Ethyl* = C^2H^5,CO^2. This salt is complete in one volume, because the radical carbon measures nothing when combined with other radicals. Two volumes of vapour contain two atoms of ethyl, because they contain two atoms of oxalate of ethyl. The salt therefore lends no support to the notion that oxalic acid is bibasic. M. Gerhardt makes the oxalates appear to be bibasic by doubling the quantities of all the components. His formula is not a demonstration but an assumption.

No. 5. *Chloride of Benzoyle* = C^7H^5,ClO. Two volumes of vapour contain two radicals uncondensed.

No. 6. *Chloride of Acetyle* = C^2H^3,ClO. Two volumes of vapour contain two radicals uncondensed.

No. 7. The compound which M. Gerhardt calls *Chloride of Sulphuryle* = Cl^2,SO^2, is that which I have described at page 56, under the designation of chlorosulphuric acid = $ClSO$. An atom of this salt = $ClSO$, measures one volume, because the chlorine alone retains its measure, the sulphur and oxygen losing theirs. Two volumes of this compound contain two complete atoms of the salt, and therefore two atoms of chlorine. M. Gerhardt's inference, that the two volumes of vapour contain *one atom of bibasic sulphuryle*, is a fallacy, founded upon the arbitrary assumption that one atom of sulphur weighs 32.

No. 8. The salt which M. Gerhardt calls chloride of carbonyle = Cl^2,CO, is that which, at page 55 of this work, is called phosgene gas = CCl,ClO, according to which formula the salt is an oxychloride of chloricformyl. Upon either supposition, the salt should have an atomic measure of two volumes; in the first case, because CO measures nothing in combination, and Cl^2 are uncondensed, and measure two volumes; in the second case, because CCl = an atom of formyl that contains Cl^1, instead of H^1, measures one volume, and ClO also measures one volume. The measure of two volumes is therefore due solely to the two volumes of chlorine, the carbon and oxygen measuring nothing. There is no evidence to prove that the compound which M. Gerhardt calls carbonyle = CO is a bibasic acid radical.

It does not appear that M. Gerhardt knew, or duly appreciated, the fact that oxygen, carbon, and sulphur have no gaseous measure when combined with radicals to form salts; and that, in the salts which contain these elements, it is the basic radicals alone that make up the measure of the compound gases. The consequence is, that his laws respecting the measure of salts that contain the so-called bibasic acids, founded as they are upon the examination of those salts only that contain sulphur and carbon as radicals, are fallacious. They apply to the exceptional cases upon which they are founded, and to nothing else. The three hundred gases described between pages 50 and 63 do not afford a single example to justify them.

I pass to the consideration of the laws that relate to tribasic acids. The Example No. 9 is equivalent to No. 2. No. 10 is a repetition of No. 4. No. 11 is a salt, the composition of which I have already discussed at page 101, where I have attempted to show that its proper measure is not two volumes, but $\frac{4}{3}$ volume. See farther particulars on this head in the account of Example No. 15. M. Gerhardt might have brought forward a more striking example in support of his law. This is the tribasic formiate of ethyl No. 2 in the Table of Irregular Gases, formulated at page 109. This salt agrees perfectly with the law in question: C^2H^5,C^2H^5,C^2H^5; CHO^3; atomic weight, 148; sp. gr. 74; atomic measure, two volumes; number of basic radicals, *three*. Unluckily, the conformity of this salt is neutralised by the nonconformity of the parallel salt No. 4 in the same Table, namely, the tribasic formiate of methyl = CH^3,CH^3,CH^3; CHO^3; atomic weight, 103; sp. gr. 35·33; number of basic radicals, *three;* atomic measure, *three* volumes. Upon two examples which neutralise one another we cannot prudently found a law having pretensions to general applicability.

The next law relates to the chlorides of tribasic acids.

No. 12. *Chloride of Boron.* I divide M. Gerhardt's atomic weight of boron by 3, which converts his formula from Cl^3B to Cl^3B^3. This formula no doubt represents *two volumes* of the gas, but, as it appears to me, it also represents *three atoms* of the salt; the small atom of boron is the equivalent of one atom of hydrogen or of chlorine. No advantage is obtained by treating as trichlorides compounds which can be just as well treated as simple chlorides. I therefore write ClB as the proper formula of the compound described at pages 52 and 104 in this work. Boron, as I understand it, is the base of a monobasic and not of a tribasic acid, and I will show in another section, that all the chemical reactions in which boron plays a part, can be described accurately and simply by equations that refer to it in its monobasic character.

No. 13. *Chloride of Phosphorus* = Cl^3P.

No. 14. *Oxychloride of Phosphorus* = Cl^3PO. I have shown at page 102 how it happens that three atoms of chlorine, in combination with an atom of phosphorus, produce two volumes of vapour, either in the presence or absence of oxygen: it is because phosphorus in all cases condenses the radicals it combines with from one volume each to half a volume, adding thereto its own measure of half a volume. It acts thus not only with chlorine but with hydrogen and with ethyl, and when the action takes place upon three atoms, the result is favourable to M. Gerhardt's law. But in this case, as in the cases of carbon and sulphur, the law depends for support upon a peculiar property of an individual substance. There is no evidence that *all* tribasic acid radicals have this power of condensation: yet the law is founded upon the assumption of its universal applicability.

No. 15. *Chloride of Cyanyl* = ClCyl. The compound in question is the solid chloride of cyanogen, the nature of which has been discussed at page 101. Two volumes of it certainly contain three atoms of Cyl because two volumes contain three atoms of the complete salt. If we admit that the compound CylCl, measuring $\frac{4}{6}$ volume, is a complete salt, the radical Cyl is monobasic. The question, whether any advantage is gained by tripling the atom, and considering it polybasic, will be considered when I come to investigate the properties of the so-called polybasic acids. The point for consideration here is the influence of polybasic acid radicals upon the measure of their gaseous salts. According to M. Gerhardt, a bibasic acid radical in all cases condenses two basic radicals, and a tribasic acid radical in all cases condenses three basic radicals into a gaseous salt, having an atomic measure of two volumes. On the other hand, my view of this matter is, that all the radicals which produce gases have individually certain unalterable properties, such as—their measure in an isolated state—their measure when combined in salts—the power possessed by certain radicals of condensing to one-half the volume of all radicals with which they combine. These properties they possess as against all other radicals; and as the properties are constant, we can foresee what will occur in the various combinations of these radicals one with another. This is the view which I have attempted to express in the Table given at page 108. The examples of salts upon which M. Gerhardt has founded his laws are all such as can be easily interpreted by these principles, and when interpreted, they prove, as I think, that M. Gerhardt's laws have not that accuracy, precision, and general applicability which he attributed to them. Founded on specialties, they apply to similar specialties and to nothing more.

A question which has been largely debated is, whether the atomic measures of all gases, simple and compound, ought to be fixed at TWO *volumes*—or, as some have it, at FOUR *volumes*. Upon this question I will not waste a word. No man whose judgment is unprejudiced can examine the facts that are detailed in this section, and in the Table given at pages 50-63, without coming to the conclusion, that the adoption of one uniform atomic measure for gases and vapours of every description is absurd.

Applications of the Radical Theory.

The object of this Essay is to show the reasonableness of the Radical Theory, and the advantages which it possesses over every other theory, in the clearness of the explanations which it affords of the proximate constitution of chemical compounds. I have dwelt at considerable length upon the compounds that produce gases and vapours, because we have in the examination of these compounds the double advantage of being able to *measure* and to *weigh* both the components and the compounds. The examination has afforded evidence more decisively favourable to the Radical Theory than any that has ever before been submitted to the consideration of chemists. I hope that the effect will be to induce them to adopt it, and to throw aside many of the limited and limiting hypotheses by which the science is now hampered. The theory of Lavoisier, that salts are composed of acids and bases; Berzelius's doctrines respecting the salts of the sesquioxides and the relations supposed to exist between the oxygen of bases and the oxygen of acids; the theory of nuclei, as developed by Laurent and Gmelin; Gerhardt's notion that "free elements" are binary compounds; and the proposal to make all salts agree with the model of water—are among the hypotheses that may be advantageously discarded as unsuited to the present condition of chemical science. The explanations of particular facts, and the generalisations which they provide, are, as I think, in all cases inferior to those that are afforded by the Radical Theory; while the formulæ and nomenclature to which they lead are so intricate and puzzling, that only a few professional chemists pretend to be able to understand them. This evil is so great, that an annual complaint is made at the meetings of the British Association, that organic chemists employ an unknown tongue, and render their science unintelligible and inaccessible to men of science of other denominations.

If the *principles* of the Radical Theory were adopted, there would remain for performance the duty of carrying the theory into practical operation—that is to say, of showing in detail its effects, firstly, upon the Classification and Nomenclature of chemical compounds; and, secondly, upon the views that ought to be taken of the proximate constitution of different varieties of compound salts; for it is upon these points that the existing theories and the Radical Theory most strikingly divaricate. That duty cannot be performed in a work of the limited extent of this Essay. My task is that of advocating a principle. I adduce such facts as serve to prove the truth of the statements that I advance, but I avoid details that would require a series of volumes for their complete exposition. Nevertheless, as it is necessary for the proper comprehension of the doctrines that I am advocating to show what effect the adoption of the Radical Theory would have upon the commonly-received formulæ and names of several important classes of chemical compounds, I shall make a *selection* of such compounds, and apply to them the Formulæ, the Names, and the Explanations, which would come into effect on the adoption of the Radical Theory, as that theory is set forth in the preceding pages. Let it, however, be borne in mind, that the NOMENCLATURE which I have suggested, though it is framed upon the Radical Theory, forms no essential part of that theory; so that the Theory and the Nomenclature must be judged of independently of each other.

Among the examples which I propose to describe, I shall select some that will give me an opportunity of discussing several questions that have not hitherto come before us; such, for instance, as relate to the doctrines of polybasic and conjugated acids; of amids, ammonias, ammoniums, and other organic bases; of vice-radicals, anhydrides, and double salts. These examples will enable us to grapple with, and dispose of, some of the most startling difficulties in theoretical chemistry.

Anhydrides, or Anhydrous Acids.

As the distinction of the proximate elements of salts into ACIDS and BASES is not recognised by the Radical Theory, it is necessary to show what view is to be taken of the compounds that are commonly called *Anhydrous Acids;* that is to say, the oxidised negative radicals, which can be procured in a separate state, or uncombined with water or metallic bases.

The following diagram exhibits examples of anhydrous acids, contrasted with hydrated acids:—

1. HO, SO

2. $\left\{\begin{array}{l}\mathbf{H}O,SO\\ \mathbf{HO},SO\end{array}\right.$

3. $\left\{\begin{array}{l}\mathbf{H}O,POO\\ \mathbf{HO},POO\end{array}\right.$

4. $\left\{\begin{array}{l}\mathbf{H}O,C^2H^3O\\ \mathbf{HO},C^2H^3O\end{array}\right.$

5. $\left\{\begin{array}{l}\mathbf{H}O,C^7H^5O\\ \mathbf{HO},C^{10}H^{11}O\end{array}\right.$

[The atomic weights of the elements in the Table are, $O = 16$, $H = 1$, $S = 16$, $C = 12$, $P = 31$.]

The compound represented by No. 1 is one atom of oil of vitriol, or hydrated sulphuric acid, the proposed systematic name for which, in accordance with the Radical Theory, and framed on the formula H,SO^2, is HYDRA SULPHETE.

No. 2 represents two atoms of hydrated sulphuric acid. If we consider these two atoms to be decomposed, by proper chemical means, into the two compounds distinguished by the different character of the types in the diagram, we have, as products, one atom of water $= H,HO$, and one atom of anhydrous sulphuric acid $= \underset{SO}{O,SO}$, or $SO + SOO$ or S,SO^3. I regard this anhydrous compound, not as an acid, for it has no acid reactions, but as a SALT, consisting of *two radicals*; the basic radical being one atom of sulphur combined with one atom of oxygen; the acid radical being one atom of sulphur combined with two atoms of oxygen. This apportionment of the oxygen is, however, only conjectural. It is quite as possible that all the oxygen may be combined with *one* of the atoms of sulphur, and that the true formula of the compound may be S,SO^3. I name this salt SULPHA SULPHITE.

It may be objected to this proposal, that chemists have always represented sulphur as an acid radical, and that there is no precedent for considering it a basic radical. But, on the other hand, it may be remarked, that chemists have never hesitated to account for certain intermediate metallic oxides by admitting them to be salts, consisting of a protoxide acting as a base, and a sesquioxide or a peroxide of the same metal acting as an acid, combined together. Why should the argument run in two opposite ways? If a metal, brought into different states of oxidation, can form both positive and negative radicals, and these can combine to produce a salt, why may not a metalloid, placed in similar circumstances, act in a similar manner? Moreover, we have to take into consideration the fact, that this salt S,SO^3 has, equally with the salt HSO^2, the power of combining with neutral salts to form multiple salts. This fact is proved by the following well-known compounds, and is corroborated by the existence of similar double salts, formed by anhydrous chromic acid with metallic chromates, and even by anhydrous acetic acid with anhydrous acetate of potash.

Sulphate.	Bisulphate.	Hydrated Sesquisulphate.	Anhydrous Bisulphate.
KSO^2	KSO^2	KSO^2	KSO^2
	HSO^2	KSO^2	KSO^2
		HSO^2	SSO^3

I shall show, in a subsequent section, that there is another acid of sulphur, which differs from hydrated sulphuric acid only in having one atom less of oxygen, so that it requires the formula H,SO; and that this acid has, like sulphuric acid, the property of forming an anhydride:

$$\left.\begin{matrix} H,SO \\ H,SO \end{matrix}\right\} \text{producing } H,HO \text{ and } S,SO.$$

This anhydrous compound must also be considered as a salt of sulphur; the unoxidised atom S being the positive radical, and the oxidised atom SO being the negative radical of the salt.

Comparison of the two series of Acids.

H,SO = Hydra sulphate.	H,SO^2 = Hydra sulphete.
S,SO = Sulpha sulphate.	S,SO^3 = Sulpha sulphite.

Diagram No. 3 exhibits the relation of hydrated phosphoric acid to anhydrous phosphoric acid. What I have said of sulphuric acid applies with equal force to phosphoric acid. The anhydrous compound POO + POOO or P,PO^5 is a salt in which phosphorus acts both as a basic radical and an acid radical, the two radicals being probably in different states of oxidation. This compound ought not to be called an acid. Its name, on the proposed system, and agreeing with the formula last quoted, P,PO^5, will be PHOSPHA PHOSPHUTE.

The other anhydrous inorganic oxygen acids may be treated precisely in the same way. Anhydrous nitric acid is formed from two atoms of the hydrated acid; $H,NO^3 + H,NO^3$ producing $H,HO + N,NO^5$ = NITRA NITRUTE; and Chromic acid, only known, and easily procured, in the anhydrous state, in beautiful red crystals, is Cr,CrO^3 = CHROMOUS CHROMITE.

In all these examples, as in all salts, the quantity of oxygen is expressed by the terminal of the name of the negative radical.

No. 4 in the diagram represents the hydrated and the anhydrous acetic acid. Notwithstanding that this substance contains a compound organic radical, I propose to deal with it precisely in the same manner as with the salts that contain simple inorganic radicals; for I consider it to be in the highest degree inexpedient to subject organic and inorganic radicals to different laws; and, by so doing, to make a chasm between organic and inorganic Chemistry, and separate two branches of knowledge, which ought to be one and indivisible.

The anhydrous acetic acid is to be considered as a salt having protoxide of acetyl = C^2H^3O for its base, and binoxide of acetyl = $C^2H^3O^2$ for its acid. Its formula, on that view of its constitution, will be $C^2H^3O,C^2H^3O^2$, or $C^2H^3,C^2H^3O^3$, and the systematic name for the latter will be ACETYLA ACETYLITE.

All the anhydrides of organic acids, of which a considerable number have recently been discovered, may be treated in the same way.

M. Gerhardt has given to anhydrous acetic acid the name of *Acetic acetate*, and as he has adopted the same system of nomenclature for the anhydrides of organic acids generally—applying, for example, such terms as Benzoic benzoate, and Cuminic cuminate, to compounds that consist of two radicals with three atoms of oxygen—I take leave to point out the unfitness of such names. The acetates, benzoates, and cuminates, contain respectively only *two* atoms of oxygen. The names proper to such salts ought not to be given to compounds which, containing *three* atoms of oxygen, evidently belong to a different series from that to which the acetates, benzoates, and cuminates belong. When the characters of a class of salts have been distinctly defined, the name of that class ought undoubtedly to be confined to compounds that agree with the definition. The present proposal, to consider the anhydrides as salts, in which the same negative radicals, in different states of oxidation, are assumed to act as positive and negative towards one another, being applicable to all anhydrides, whether their radicals be simple or compound, presents, at least, the good qualities of simplicity, uniformity, and precision, both in formulæ and nomenclature.

No. 5 in the diagram $= \left\{\begin{matrix}\mathbf{H}O,C^7H^5O \\ \mathbf{HO},C^{10}H^{11}O\end{matrix}\right\}$ illustrates the formation of a compound procured lately by M. Gerhardt. This is a double anhydride of a kind that appears to be as plentiful as the anhydrides of the individual organic acids. The radicals represented in No. 5 are benzyl $= C^7H^5$ and cumyl $= C^{10}H^{11}$. These are combined, with three atoms of oxygen, into a compound of the same structure as anhydrous acetic acid. The origin of the compound is to be explained exactly in the same manner as that of the simple anhydrides; namely, two atoms of hydrated acid produce one atom of water and one atom of the anhydride:—

$$\left.\begin{array}{l}\text{Benzoic acid} = H,C^7H^5O^2 \\ \text{Cumenic acid} = H,C^{10}H^{11}O^2\end{array}\right\} = \left\{\begin{array}{l}C^7H^5O^2 \\ C^{10}H^{11}O\end{array}\right\} + \left\{\begin{array}{l}H \\ HO\end{array}\right.$$

M. Gerhardt calls this anhydride by the following names: "Anhydrous Benzo-cuminic acid," "Cuminate of Benzoile," and "Benzoate of Cumyl." For want of a System of Nomenclature which would indicate to him a *single satisfactory name*, he begins with a profusion of synonymes. This is an example of the manner in which our books on Organic Chemistry become incumbered with useless or mischief-making names.

The terms "cuminate of benzoile" and "benzoate of cumyl" are both improper, for the reasons urged in reference to the names of the simple anhydrous acids; namely, because cuminates and benzoates are salts that contain each only *two* atoms of oxygen, and it is contrary to chemical logic to apply the same names to salts that contain *three* atoms of oxygen.

The term "anhydrous benzo-cuminic acid" is improper for another reason, namely, because it is not an acid, and does not give rise to a series of salts in which "benzo-cumyl" forms the acid radical. On the contrary, when the anhydride is placed in the presence of basic radicals, the benzyl and cumyl fall apart, and produce benzoates and cuminates. In fact, this anhydride differs in no respect from the compound ethers and acetones that are described in group 5, page 66, excepting that its radicals are in a higher state of oxidation. I propose, therefore, to consider it as a salt, in which the radical with the greater proportion of hydrogen shall, on the principle explained at page 73, be taken to be the basic radical, and the one with the lesser proportion of hydrogen shall be taken to be the acid radical. The analytical formula of the salt will then be $C^{10}H^{11}O,C^{7}H^{5}O^{2}$; its synoptical formula will be $C^{10}H^{11},C^{7}H^{5}O^{3}$; and its systematic name will be CUMYLA BENZYLITE.

All the anhydrides that contain two organic radicals, combined with three atoms of oxygen, may be formulated and named in accordance with this example. The following compounds of this class have been recently discovered by MM. Gerhardt and Chiozza.[1]

$C^{9}H^{17}, C^{7}H^{5}O^{3}$ = Pelargyla Benzylite.
$C^{7}H^{13}, C^{10}H^{11}O^{3}$ = Œnanthyla Cumylite.
$C^{5}H^{9}, C^{7}H^{5}O^{3}$ = Valeryla Benzylite.
$C^{2}H^{3}, C^{10}H^{11}O^{3}$ = Acetyla Cumylite.
$C^{2}H^{3}, C^{9}H^{7}O^{3}$ = Acetyla Cinnamylite.
$C^{2}H^{3}, C^{7}H^{5}O^{3}$ = Acetyla Benzylite.
$C^{10}H^{11}, C^{7}H^{5}O^{3}$ = Cumyla Benzylite.
$C^{9}H^{7}, C^{7}H^{5}O^{3}$ = Cinnamyla Benzylite.

Degrees of Oxidation of Radicals.

The compound radicals appear to have the same degrees of oxidation as the elementary radicals. If R is the radical, we have the series:—

1. R,RO
2. RO
3. RO,ROO = R,RO^{2}
4. ROO

No. 1 is what we now term a protoxide, namely, the oxide formed on the model of water.

No. 2 is the oxide that exists in the salts that have the formula MRO^{2} or MO + RO, but which is rarely obtained in a separate state. Professor Williamson has given to an oxide of this description, a name which entirely differs from that of its characteristic radical. He designates the protoxide of acetyl = $C^{2}H^{3}O$ by the term OTHYL. If this precedent is followed, we must have *a pair of names* for every radical; one name for the radical alone, and another, entirely different, for one of its oxides. The evil may not stop there. If RO is to have a name essentially different from that of R, why may not RRO, ROO, R,RO^{2}, and all other oxides of the radical, also be distinguished by widely-different names? Surely it is better to adopt a system of names, which shall not lose sight of each radical by the time we reach its first oxide.

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[1] Quarterly Journal of the Chemical Society. V. 127, 226. VI. 182, 184.

According to the nomenclature which I have proposed, C^2H^3O will be named **Acetylate**, which, without special definition, signifies one atom of acetyl and one atom of oxygen. Such words as *othyl* must require definition individually; for othyl indicates neither acetyl nor oxygen.

It may be replied to this objection, that the reason why two different names are given to the compounds in question is, that acetyl = C^2H^3 and othyl = C^2H^3O are two different radicals. That reply rests, however, not on a matter of fact, but on a matter of opinion. According to the radical theory, as I understand it, othyl is not a radical, but the oxide of a radical, and it has no right to any other name than that which declares it to be the oxide of a radical.

The oxides, No. 3, = RO, ROO, or R,RO^3, are the anhydrides of which I have just treated.

No. 4, = ROO. This oxide probably occurs in the salts that contain O^3 and O^4.

$$\text{Thus:}\quad \begin{aligned} MO,ROO &= M,RO^3 \\ MOO,ROO &= M,RO^4 \end{aligned}$$

Intermediate Metallic Oxides.

In reference to the classification of oxides, I may say a few words respecting those metallic oxides which occur between the protoxides and the sesquioxides, and which commonly receive the formulæ M^3O^4 and $MO + M^2O^3$; the latter representing the compounds as salts in which different oxides of the same metal act as base and acid to one another. The following formulæ represent examples of such oxides:—

$FeO + Fe^2O^3 = Fe^3O^4$ Magnetic oxide of iron.
$MnO + Mn^2O^3 = Mn^3O^4$ Red oxide of manganese.
$CrO + Cr^2O^3 = Cr^3O^4$ Chromoso-chromic oxide.

M. Laurent accounts for salts of this description, by adopting a *third equivalent* of the metals which they contain. But this proposal is inadmissible, because the fourth part of the metal contained in such compounds is not the equivalent of a single volume of hydrogen, nor does it make a series of salts, corresponding to those which are made by the basylous and basylic equivalents of the respective metals. I consider these oxides to be compounds of the basylous and basylic oxides, according to the following general formula:—

$McMcO + McMO = Mc^3MO^2$. Thus,—

Magnetic oxide of iron = $FecFecO,FecFeO = Fec^3FeO^2$
Red oxide of manganese = $MncMncO,MncMnO = Mnc^3MnO^2$
Chromoso-chromic oxide = $CrcCrcO,CrcCrO = Crc^3CrO^2$

Corresponding nomenclature:

Fec^3FeO^2 = Ferrinic ferrete.
Mnc^3MnO^2 = Manginic manganete.
Crc^3CrO^2 = Chrominic chromete.

Aldides, or Aldehydes in general.

Gmelin describes[1] the aldides as follows:—"When Liebig, by withdrawing two atoms of hydrogen from alcohol, converted it into the compound $C^4H^4O^2$, he called that compound *aldehyde*, from *al*cohol and *dehyd*rogenated. More recently a considerable number of other compounds have been discovered, possessing a certain analogy with Liebig's aldehyde, and to these the same name has been extended. To avoid this confusion, I propose to denote all these compounds by the generic term *Aldide*, reserving the original title of aldehyde for the aldide of the ethyl series."

He then goes into a description, classification, and enumeration of the aldides: see the work referred to. It will suffice for my purpose to extract a few examples from his list. Let me premise, that the fundamental experiment, referred to above, of the production of aldehyde from alcohol is, on the radical theory, to be explained as follows:—

$$H,C^2H^5O - H^2 = H,C^2H^3O.$$

Namely, the radical ethyl is reduced to the radical acetyl by the abstraction of two atoms of hydrogen. See the explanation of this theory at page 74. Both alcohol and aldehyde are salts of the same structure: they belong to the hydrated oxides, of which examples are given in group 3, page 65. Many of Gmelin's aldides are precisely of this character. I have treated, at page 78, of the production of aldides of this class. Several of Gmelin's aldides belong to the anhydrides described in the last section; others belong to the oxychlorides, of which examples are given in group 10, page 68; and others are of the class of amids, of which I shall treat in a subsequent section. In short, the aldides, as grouped by Gmelin, are compounds belonging to many different series of salts, transformed into the so-called aldides by the abstraction, not only of hydrogen, but of carbon or oxygen, or sometimes of all three; and having scarcely any common relation:—

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[1] Handbook of Chemistry. VII. 192.

Gmelin's Names.	Proposed Formulæ.	Proposed Names.
a. Hydrates.		
Aldehyde	H,C^2H^3O	Hydra acetylate.
Acrolein	H,C^3H^3O	Hydra acrylate.
Butyric aldide	H,C^4H^7O	Hydra butyrylate.
Valeric aldide	H,C^5H^9O	Hydra valerylate.
Phenous acid	H,C^6H^5O	Hydra phenylate.
Oil of bitter almonds	H,C^7H^5O	Hydra benzylate.
Œnanthol	$H,C^7H^{13}O$	Hydra Œnanthylate.
Chloral	H,C^2Cl^3O	Hydra Chlorinic-acetylate.
b. Anhydrous Acids.		
Lactic acid	$C^3H^5,C^3H^5O^5$.	Lactyla lactylate.
Maleic Acid	$C^2H\,,C^2H\,O^3$.	Maleyla maleylite.
c. Oxychlorides.		
Chloraldehyde	C^2Cl^3,ClO	Chlorinic-acetyla chlorate.
Chlorobenzoyl	C^7H^5,ClO	Benzyla chlorate.
d. Cyanates.		
Cyanic acid	H,CyO	Hydra cyanate.
Urea	NH^4,CyO	Ammona cyanate.
e. Amids.		
Oxamide	NH^2,CO	Amida Carbate.

At page 81 I have defined aldide in terms intended to fix its meaning and restrict its use.

The Chromates.

I introduce the chromates in this place, because they exhibit some striking examples of the combination of anhydrides with neutral salts.

The anhydrous crystallized chromic acid is composed of—

Chromium . . 54 = Cr^2
Oxygen . . . 48 = O^3

It consequently belongs to the class of Anhydrides, and requires the formula Cr,CrO^3, and the name Chromous chromite. The solid hydrate of this acid is unknown, although the anhydrous acid readily dissolves in water, and the solution may be supposed to contain $HCrO^2$; agreeably to the equation,

$$H,HO + Cr,CrO^3 = HCrO^2 + HCrO^2$$

The acid in this aqueous solution combines with peroxide of hydrogen = HO. The compound has a deep indigo-blue colour, but it is unstable, and cannot be separated from the water of solution. Its composition is probably

$$\mathrm{HO{,}CrO + HO = H{,}H;\ CrO^3.}$$

There are three combinations of chromic acid with potash, which have the following composition:

Chromate of Potash.—Usual formula, $\mathrm{KO{,}CrO^3}$. Doubling the atomic weight of the oxygen we have $\mathrm{KCrO^2}$.

Bichromate of Potash.—Usual formula $\mathrm{KO{,}CrO^3{,}CrO^3}$ Doubling the atomic weight of the oxygen we have $\mathrm{1K{,}2Cr{,}3\frac{1}{2}O}$. Doubling the formula, to get rid of fractions, we have $\mathrm{K^2Cr^4O^7}$.

Terchromate of Potash.—Usual formula, $\mathrm{KO{,}3CrO^3}$. Doubling the atomic weight of the oxygen, this gives us $\mathrm{KCr^3O^5}$.

If we regard the chromate as the normal salt = $\mathrm{KCrO^2}$, the terchromate is a compound of normal chromate and chromic acid, atom to atom, and the bichromate is a compound of the normal chromate with the terchromate.

$$\begin{array}{lll}\text{Chromate} & = \mathrm{KCrO^2} & = \mathrm{K\,Cr\,O^2} \\ \text{Bichromate} & = \mathrm{KCrO^2 + (KCrO^2 + CrCrO^3)} & = \mathrm{K^2Cr^4O^7} \\ \text{Terchromate} & = \mathrm{KCrO^3 + CrCrO^3} & = \mathrm{K\,Cr^3O^5}\end{array}$$

This series is similar to that of the three kinds of phosphates, excepting that, in the present case, it is the *acid* radical which is variable, while in the phosphates it is the *basic* radical that is variable.

The systematic names of these salts are as follow:—

Chromate of potash . .	$\mathrm{K\,Cr\,O^2}$	= Potassa chromete.
Terchromate of potash .	$\mathrm{K\,Cr^3O^5}$	= Potassa chrominute.
Bichromate of potash . .	$\mathrm{K^2Cr^4O^7}$	= Potassen chromoneze.

There is a salt formed by means of chromic acid and chloride of potassium which has given theoretical chemists a great deal of trouble. Here are two of its formulæ and names:—

$$\mathrm{KCl.\ 2CrO^3} = \text{Bichromate of chloride of potassium.}$$

$$\mathrm{KO.\left(Cr\left\{\begin{matrix}O^2\\ Cl\end{matrix}\right)\right.CrO^3} = \text{Chrombioxychlorid-chromate of potash.}$$

This salt is probably a compound of neutral chromate of potash = $\mathrm{KCrO^2}$, with the oxychloride of chromium = ClCrO, so that its formula may be $\mathrm{KCrO^2 + ClCrO}$ or $\mathrm{K{,}Cl;\ Cr^2O^3}$. The systematic name, according to this last formula, is Potassa chlora chromenite.

There is a corresponding salt containing sulphur instead of chromium —the sulphur bioxychlorid-sulphate of potash,

$$= \mathrm{KO.}(\mathrm{S}\left\{\begin{matrix}\mathrm{O}^2\\ \mathrm{Cl}\end{matrix}\right.\mathrm{.SO}^3.$$

This salt is probably a compound of neutral sulphate of potash = KSO^2 with the oxychloride of sulphur = $ClSO$, producing the compound $KSO^2 + ClSO$ or $K,Cl;\ S^2O^3$, the name for which is Potassa chlora sulphenite.

The chromates combine with one another to produce compound salts:

Double: $KCrO^2 + CaCrO^2 = K,Ca;\ (CrO^2)^2$.
Triple: $2KCrO^2 + NaCrO^2 = K^2Na;\ (CrO^2)^3$.
Sextuple: $AmCrO^2 + 5HCrO^2 = Am,H^5;\ (CrO^2)^6$.

Is the chromic acid monobasic, bibasic, tribasic, or sexbasic?

Distinction between Analytical Formulæ and Synoptical Formulæ.

In the preceding pages I have frequently shown, that the radical theory permits of the representation of salts by two kinds of formulæ; as a simple example of which I may quote the formulæ employed to represent the sulphates, viz.:—

$$MO,SO \quad \text{and} \quad MSO^2.$$

The formula MSO^2 is that which expresses all that we certainly *know* of the constitution of the sulphates, and the arrangement of the symbols is conventional. We *agree* (that is the strongest ground that we can put it upon—we *agree*) to put *first* the electro-positive or basic radical, and, *after it*, the electro-negative or acid radical; and, *at the end*, we put the oxygen, because we do not know where else to put it. This formula gives a synoptical view of our *knowledge* of this compound, and I propose to call it a *synoptical formula.*

In the other formula, MO,SO, we show what we *conjecture* to be the proximate constitution of the sulphate. In our *mental analysis* of this salt, we figure to ourselves, that it is a compound of oxidised metal and oxidised sulphur, atom to atom. But mental analysis is purely theoretical, and we cannot experimentally establish the truth of this formula. Nevertheless, the analytical view of the compound assists our comprehension of many phenomena that occur when the salt is decomposed by reaction with other salts; and, in many theoretical inquiries, where our judgment must be entirely guided by circumstantial evidence, the *analytical formulæ* of salts are important.

The systematic nomenclature which I have proposed for adoption is founded upon the synoptical formulæ, partly because these are less subject to variation than the analytical formulæ, and partly because they yield shorter and simpler names. It is, however, always possible, whenever it is considered desirable, to give names to the conjectured components of a salt as set forth in an analytical formula. Thus, we may call the sulphate of barytes:

Synoptical formulæ: $BaSO^4$ . . Baryta sulphete.
Analytical formulæ: BaO,SO . Barytate sulphate.

The power of writing names to suit either formula is frequently useful, particularly in the discrimination of multiple salts.

Sir Humphry Davy on the Composition of Sulphates and Salts in General.

Since the article on the binary theory of salts, at page 18, went to press, a chemical friend has directed my notice to another note of Sir H. Davy's, respecting the question there discussed. As I desire to do justice to that great chemist, I copy the article in full:—

"The extensive class of bodies called neutral salts," says Davy,[1] "are formed by the mutual action of acids and oxides, alkalies and earths; and in general those oxidated bodies that contain least oxygen are such as most readily enter into combination with acids; thus the peroxides generally are either insoluble in acids, or require the abstraction of a portion of oxygen to become soluble; and, in general, two inflammable bodies, in combining with oxygen, unite to less than the added sums of the quantity they would separately combine with to saturation. Many of the neutral salts may be considered either as combinations of peroxides with inflammable bases or as alkalies united to acids, or as peroxides united to oxides; for instance, the compound formed from sulphurous acid gas and potassa consists of potassium and sulphur, with three proportions of oxygen, and may be regarded as a compound of peroxide of potassium and sulphur. Sulphate of potassa contains four proportions of oxygen, and might be regarded as a compound of peroxide of potassium and oxide of sulphur. They are, in fact, all compounds of oxygen with double bases; and when one fixed alkali, or earth, or oxide, separates another, it may be supposed that the basis only is changed: thus, where hydrate of potassa separates lime from its nitric solution, it may be conceived that the potassium only takes the place of calcium, and that the oxygen and water of the hydrate of potassium unite to this metal, and that the potassium unites to the oxygen, nitrous acid and water of the solution.

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[1] Elements of Chemical Philosophy, Collected Works (1840), vol. iv. page 368. First published in 1812.

"It is very easy to estimate the composition of any of the combinations of alkalies, earths, or oxides with acids, by adding together the numbers representing their elements: thus, sulphate of soda is composed of 60 sulphur, 90 oxygen, which make two proportions of sulphuric acid; and 88 of sodium and 30 of oxygen, which make one proportion of soda. Carbonate of lead is composed of two proportions of carbonic acid, equal to 82·8, two proportions of oxygen 30, and one of lead 398. Sulphate of lead is composed of two proportions of sulphuric acid 150, two of oxygen 30, and one of lead 398: sulphate of nickel of two proportions of sulphuric acid 150, and one of oxide of nickel 141; and these proportions agree almost precisely with the best analysis.

"It appears that in the neutrosaline compounds, in which there is a perfect harmony between the proportions of the elements, the result is neutralisation; and that in this case a crystalline compound or an insoluble compound is usually formed. Thus, in the instances above mentioned, in the sulphates of soda and lead, the sulphur is a binary proportion, and the oxygen a binary proportion, or a multiple of a binary proportion; and in the carbonate of lead the carbon is a binary proportion, and the oxygen a multiple of a binary proportion; and, to give another instance, in the sulphate of barytes the sulphur is a single proportion, and the oxygen a single proportion, or a multiple.

"When, on the contrary, there is a want of harmony in the proportions, the excess either of acid or basis seems to be shown in the properties of the result, and it is seldom a crystallized body. Thus, in the soluble red sulphate of iron, the number of proportions of oxygen in the oxide are three, and those of the sulphur in the acid are four, and this body is strongly acid and uncrystallizable."

This note, printed in 1812, does not essentially differ from the notes subsequently published in 1815 and 1816, and which I have quoted at page 21. Davy had, previous to any of these dates, proved that chloride of sodium contained only chlorine and sodium; that no oxygen was present, and therefore no soda; no hydrogen, and therefore no hydrochloric acid. The substance that was *par excellence* a SALT, was found to contain neither *acid* nor *base*. This discovery naturally led him to form generalisations respecting other salts. He might reasonably ask these questions: Since we *know* that muriate of soda contains neither muriatic acid nor soda, what certainty have we that sulphate of soda contains sulphuric acid and soda? May not this salt, and all salts, be composed in a manner analogous to muriate of soda? These were very natural suggestions, and the evidence before us proves that they passed through Davy's mind, and that he was the first to point out the fact, that Lavoisier's theory of acids and bases did not rest on a logical basis. But it does not appear to me that Davy went much beyond this expression of his conviction that the existing theory of the salts was bad, and that it was desirable to have a better theory. He opens the case for discussion very clearly. He says, "Many of the neutral salts may be considered either as—

a. Combinations of peroxides with inflammable bases, or as
b. Alkalies united to acids, or as
c. Peroxides united to oxides."

In proposition *a*, he allots all the oxygen to the basic radical $= MO + R$. In *b*, the usual theory is accepted $= MO + RO^3$. In *c*, the oxygen is supposed to be equally divided between the positive and negative radicals, $MO + RO$; and this last proposition is illustrated by supposing the sulphate of potash to be composed of peroxide of potassium and sulphurous acid $= KO^2 + SO^2$. This last was certainly a most valuable suggestion. There is no statement in these propositions, nor anywhere in the note, that Davy supposed the sulphates to be so constituted, that all the oxygen was combined with the sulphur; according to the formula which Dumas assigned to him $= K + SO^4$.

But after opening the case for inquiry, Davy did not pursue it with much precision. He states, first, that sulphate of potash contains four proportions of oxygen; then, that the sulphates of soda, lead, and nickel contain each two proportions of sulphur, eight proportions of oxygen, and one proportion of metal; and, finally, that in the sulphate of barytes the sulphur is a single proportion, and the oxygen a single proportion, or a multiple. The most important sentence in the note is that where he says, that "the salts are, in fact, all compounds of oxygen with double bases; and when one fixed alkali, or earth, or oxide, separates another, it may be supposed that the *basis only is changed*: thus, where hydrate of potassa separates lime from its nitric solution, it may be conceived that the potassium only takes the place of calcium." With this exception, there is in this note no distinct setting forth of any new and peculiar theory of the salts; and it remains to be shown whether any such theory was published by Davy, or anybody else, between 1816 and the date of Dr. Clark's Syllabus of 1826.

One of Davy's instances deserves special notice:—"Sulphate of potash contains four proportions of oxygen, and might be regarded as a compound of peroxide of potassium and oxide of sulphur." The theory contained in this sentence, instead of being the *binary theory*, $= K + SO^4$, which Dumas attributes to Davy (see page 19), is precisely the theory $KO + SO$, which he attributes to Longchamp (see page 23), and which he calls "the hypothesis of Davy turned topsy-turvy;" so that, actually, the praises which Dumas bestowed upon Sir H. Davy belong to Dr. Clark, while the sneers which he lavished upon M. Longchamp are the property of Sir H. Davy.

Vice-Radicals.

In explaining the doctrine of chemical types and substitutions, I stated that the hydrocarbon radicals produced a series of secondary radicals, by exchanging part or the whole of their hydrogen, atom for atom, for chlorine, bromine, or iodine; and, in the inquiry respecting gaseous volumes, I showed that the secondary radicals, thus produced, acted in salts the same part as the radicals from which they were derived, excepting only that the basic energy of the positive radicals diminished in proportion to the increase in the number of the substituting atoms of the negative metalloid. The reader will consult pages 93 and 101 for a detailed illustration of these general principles.

The compound chlorine radicals, produced in the manner that I have described, and having the property of acting *vicariously*, or as *substitutes*, for the original radicals from which they are derived—doing the duty of those radicals more or less imperfectly, as the duties of principals commonly are done by substitutes—form but one division of a series of Vicarial or Vice-Radicals that are found among the compounds of organic chemistry. The chlorine radicals were first referred to, because many of them are volatile, and it was necessary that we should understand their constitution, in order to comprehend certain doctrines respecting the measure of the gases; but I shall now give a short notice of such radicals taken generally, and including those which are fixed, as well as those which are volatile. They may be arranged in four classes. 1. Vice-radicals, in which the hydrogen of the original radicals is replaced by chlorine. These I shall call *Chloric Radicals*. The iodic- and bromic-radicals, form parallel series, belonging to the same class. 2, Those in which the hydrogen is replaced by nitrogen. These I shall call *Zotic Radicals*. 3. Those in which the hydrogen is replaced by sulphur, which I shall call *Sulphic Radicals*. 4. Those in which the hydrogen is replaced by metals, which may be distinguished as *Metallic Vice-Radicals*.

I. Chloric Radicals.

The account of the chloric radicals, already given at pages 93 and 101, leaves but a few remarks unsaid. When the chlorine is introduced into a negative or acid radical, the vice-radical is also negative, and in forming salts with positive radicals, it acts in the same manner as the original radicals. In being monobasic or bibasic, in forming salts with one atom of oxygen, or with two atoms or three atoms, and in similar particulars, the vicar and the principal radical agree perfectly. Generally, also, the salts of the chloric radical have the same external appearance as those of the hydro-carbon radical. Their solutions do not give a precipitate with solutions of silver, and the presence of the chlorine can only be demonstrated by a process which destroys the compound. The following are examples of salts that contain chloric radicals, placed in juxtaposition with the corresponding salts of the original radicals. The nomenclature has been explained at page 94:—

Radicals.		Salts.	
Acetyl	C^2H^3	$H,C^2H^3O^2$.	Hydrated acetic acid. Hydra acetylete.
	C^2Cl^3	$H,C^2Cl^3O^2$.	Hydrated trichloracetic acid. Hydra chlorinic-acetylete.
Valeryl	C^5H^9	$H,C^5H^9O^2$.	Hydrated valerianic acid. Hydra valerylete.
	$C^5H^5Cl^4$	$H,C^5H^5Cl^4O^2$	Hydrated quadrichlorovaleric acid. Hydra chloronic-valerylete.
Benzyl	C^7H^5	$H,C^7H^5O^2$.	Hydrated benzoic acid. Hydra benzylete.
	C^7H^4Cl	$H,C^7H^4ClO^2$.	Hydrated chlorobenzoic acid. Hydra chloric-benzylete.
Phenyl	C^6H^5	H,C^6H^5O .	Hydrated phenic acid. Hydra phenylate.
	$C^6H^3Cl^2$	$H,C^6H^3Cl^2O$.	Hydrated bichlorophenic acid. Hydra chlorenic-phenylate.
	$C^6H^2Cl^3$	$H,C^6H^2Cl^3O$.	Hydrated trichlorophenic acid. Hydra chlorinic-phenylate.
	C^6Cl^5	H,C^6Cl^5O .	Hydrated quintichlorophenic acid. Hydra chlorunic-phenylate.

The vice-radicals formed by iodine and bromine are similar in constitution and functions to those formed by chlorine. I refer the reader for examples to the sections on Indigo and Aniline.

II. Zotic Radicals.

The acids of zotic radicals are generally produced by dissolving certain organic acids in fuming nitric acid, or in a mixture of nitric acid and concentrated sulphuric acid. The reaction may be represented as follows:—

Employed.		Produced.
Benzoic acid . .	$H,C^7H^5O^2$	$H,C^7H^4NO^4$.
Nitric acid . . .	$H,N\ \ O^3$	$H,\ H\ \ O$.

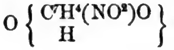
Namely, an atom of hydrated benzoic acid and an atom of hydrated nitric acid, produce an atom of water and an atom of hydrated nitrobenzoic acid.

In contemplating the composition of this new acid, we perceive two remarkable peculiarities:—In the first place, the radical benzyl = C^7H^5 is converted, by the substitution of an atom of nitrogen for an atom of hydrogen, into the vice-radical C^7H^4N, or, as I have proposed to formulate it (page 94), into C^7H^4Z; for which formula the systematic name will be *zotic-benzyl*. In the second place, we perceive that the acid formed by the vice-radical contains two atoms more of oxygen than are contained in the acid formed by the original radical. This is not a property belonging to this individual example, but is a characteristic of all the zotic radicals which contain carbon. For every atom of nitrogen which is carried into any radical, in substitution for an atom of hydrogen, two atoms of oxygen are carried into the salts of that radical; and this is continued to the amount of three atoms of nitrogen, beyond which number substitution by this element rarely extends. The following are therefore the proportions and general limits of the zotic radicals:—

	Expelled from the original Radicals.	Substituted.
Zotic radicals	H^1.	$Z^1 + O^2$.
Zotenic radicals . . .	H^2.	$Z^2 + O^4$.
Zotinic radicals . . .	H^3.	$Z^3 + O^6$.

In two respects the zotic radicals differ essentially from the chloric radicals. The first is, that in the latter there is no limitation to the number of atoms of chlorine that can replace atoms of hydrogen: substitution may proceed till all the hydrogen of any radical is replaced by chlorine. The second point of difference is, that the salts of the chloric radicals contain in all cases the same quantity of oxygen as the salts of the primary radicals from which they are formed.

The circumstance that every atom of nitrogen that goes into a zotic radical is accompanied in its transit by two atoms of oxygen has induced many chemists to conclude, that the actual substitute for each atom of hydrogen which nitric acid expels from a radical is not an atom of nitrogen = N, but an atom of peroxide of nitrogen = NO^2, and this conclusion has induced them to formulate the salts of the zotic radicals in such a manner as to show that two atoms of oxygen in company with each atom of nitrogen are situated in the body of the compound radical. Thus:—



$$O\left\{\begin{matrix} C^7H^4(NO^2)O \\ H \end{matrix}\right\} = \text{Hydrated nitrobenzoic acid.}$$

This symbol affects to show us, that there is in this salt one atom of oxygen that is equally combined, on the one hand, with a single atom of basic hydrogen, and on the other hand, with a complex acid radical. This complex acid radical is itself an oxide containing one atom of oxygen in combination with a nitro-conjugated radical = $C^7H^4(NO^2) + O$. This nitro-conjugated radical = $C^7H^4(NO^2)$ is fundamentally benzyl = C^7H^5, but it is benzyl which contains peroxide of nitrogen, instead of one atom of hydrogen = $C^7H^4 + NO^2$. Here, therefore, we have oxygen represented to be distributed in three places, combined with three different degrees of intensity, to the radicals of the salt—we have, consequently, assumptions upon assumptions three deep, which can be justified or established by no evidence, and which serve no useful purpose. The symbol $O\left\{\begin{matrix}C^7H^4(NO^2)O\\H\end{matrix}\right\}$ is an affectation of knowledge—a pretentious accuracy—in a matter where accurate knowledge is unattainable. It serves neither to register nor to convey knowledge, for it represents nothing but a speculation. I should not quarrel with it, if it were *confessedly* a speculation. What I complain of is, the practice too common among organic chemists, of stating such speculative views as if they represented demonstrated facts. Until we learn something *certain* respecting the distribution of oxygen between the positive and negative radicals of a salt, the honest, modest, prudent course for us to follow is, to put the oxygen together, and frankly confess that we do not divide it between the radicals, because we do not know how to do so with the slightest pretensions to accuracy and truth.

Applying this notion to the nitrobenzoic acid, the formula becomes $H,C^7H^4ZO^4$.

The leading properties of the salts of the zotic radicals are as follow: They are all monobasic. They have usually a yellow colour. Bitter. Commonly decomposed by heat, so that they do not form gases. The decomposition by heat is generally explosive. It is possible, therefore, that the nitrogen which they contain may be present in that condensed condition which I have referred to in the article on Cyanyl (page 101).

Examples of Salts containing Zotic Radicals.

Radicals.		Salts.	
Propionyl	C^3H^5	$H,C^3H^5O^2$.	Hydrated propionic acid. Hydra propionylete.
	C^3H^4Z	$H,C^3H^4ZO^4$	Hydrated nitropropionic acid. Hydra zotic-propionylote.

Radicals.		Salts.	
Phenyl .	C^6H^5	H,C^6H^5O .	Hydrated phenic acid. Hydra phenylate.
	$C^6H^3Z^2$	$H,C^6H^3Z^2O^5$	Hydrated binitrophenic acid. Hydra zotenic-phenylute.
	$C^6H^2Z^3$	$H,C^6H^2Z^3O^7$	Hydrated trinitrophenic acid. Hydra zotinic-phenyleze.
Benzyl .	C^7H^5	$H,C^7H^5O^2$.	Hydrated benzoic acid. Hydra benzylete.
	C^7H^4Z	$H,C^7H^4ZO^4$	Hydrated nitrobenzoic acid. Hydra zotic-benzylote.
	$C^7H^3Z^2$	$H,C^7H^3Z^2O^6$	Hydrated binitrobenzoic acid. Hydra zotenic-benzylaze.
Cinnamyl	C^9H^7	$H,C^9H^7O^2$.	Hydrated cinnamic acid Hydra cinnamylete.
	C^9H^6Z	$H,C^9H^6ZO^4$	Hydrated nitrocinnamic acid. Hydra zotic-cinnamylote.

Lest it should be imagined that I lose sight of the difficulties that attend the management of the zotic radicals, I will cite a couple of very perplexing examples from an article on the Benzoates, written by Dr. H. Kolbe.[1]

"Benzoate of oxide of phenyl (benzophenid of Laurent and Gerhardt) $(C^{12}H^5)O,C^{14}H^5O^3$."—*Kolbe.*

According to my notation this compound is $C^6H^5,C^7H^5O^2$, name phenyla benzylete.

"Benzoate of oxide of binitrophenyl. (Binitrobenzophenid of Laurent and Gerhardt.)

$$C^{12}\left\{\begin{matrix}H^3\\(NO^4)^2\end{matrix}\right\}O.\ C^{14}H^5O^3.\text{"—}\textit{Kolbe.}$$

According to this formula, three-fourths of the oxygen of the salt is combined with the basic radical and one-fourth with the acid radical. According to my notation, the synoptical formula is $C^6H^3Z^2,C^7H^5O^6$, and the systematic name is zotenic-phenyla benzylaze.

"Benzoate of oxide of trinitrophenyl. (Trinitrobenzophenid of Laurent and Gerhardt.)

$$C^{12}\left\{\begin{matrix}H^2\\(NO^4)^3\end{matrix}\right\}O.\ C^{14}H^5O^3.\text{"—}\textit{Kolbe.}$$

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[1] Supplemente zum Handwörterbuche der Chemie (1852), p. 503.

According to this formula, thirteen-sixteenths of the oxygen of the salt is combined with the basic radical, and only three-sixteenths with the acid radical. According to my notation, the synoptical formula is $C^6H^2Z^3,C^7H^5O^8$, and the systematic name is zotinic-phenyla benzylize.

If I wanted to make analytical formulæ for the last two compounds, I should reason in this way: The analytical formula of the phenic acid is H,C^6H^5O, and that of the benzoic acid is HO,C^7H^5O. If the basic H in the last formula is replaced by phenyl, we have the salt C^6H^5O,C^7H^5O, as exhibited in the first of the above three examples.

If the replacing radical is zotenic-phenyla = $C^6H^3Z^2$, the resulting salt must account for the four atoms of oxygen which always accompany Z^2, when acting as substitute for H^2, and we have consequently the analytical formula $C^6H^3Z^2O^5,C^7H^5O$. The O^5 consists of the O^1 belonging to the original phenylate, and the O^4 brought into the compound by the Z^2.

In like manner, the vice-radical $C^6H^2Z^3$ gives rise to a compound which requires the analytical formula $C^6H^2Z^3O^7,C^7H^5O$.

The inspection of these analytical formulæ gives rise to an important question. Can the oxidised radical C^7H^5O act as an acid radical against such oxidised radicals as $C^6H^3Z^2O^5$ and $C^6H^2Z^3O^7$ taken as basic radicals? Is such an action certain—is it possible—probable—plausible? No! certainly not. It would be just as extravagant to assume that, in sulphate of potash, SO^3 acted as a base against KO as an acid. But what opinion ought we to form of these salts?

The salts in question are produced by the action of chloride of benzyl (C^7H^5ClO) upon binitrophenic acid = $H,C^6H^3Z^2O^5$ and trinitrophenic acid = $H,C^6H^2Z^3O^7$. But the action which takes place is such as throws the benzyl out of the condition of a basic radical into the condition of an acid radical, because the salts finally produced contain respectively six and eight atoms of oxygen, whereas if phenyl were the acid radical, the atoms of oxygen in the salts would be respectively five and seven. I think therefore that in the formation of these salts, the nitrogen passes from the phenyl radicals into the benzyl radicals, and that the final products of the two processes are as follows:—

$C^6H^5O,C^7H^3Z^2O^5$ = $C^6H^5,C^7H^3Z^2O^6$ = Phenyla zotenic-benzylaze.
$C^6H^5O,C^7H^2Z^3O^7$ = $C^6H^5,C^7H^2Z^3O^8$ = Phenyla zotinic-benzylize.

The salts formed by zotic radicals are all *monobasic*, because there is present in each of them only *one acid radical*, whatever may be the quantity of azote they contain.

III. Sulphic Radicals.

The salts that contain the sulphic radicals are produced by subjecting organic acids to the action of anhydrous sulphuric acid, or of oil of vitriol. Each sulphic radical consists of one atom of an organic negative radical *minus* one atom of hydrogen *plus* one atom of sulphur; and in its salts there is always present one atom more of oxygen than belongs to salts of the same organic radical in its normal state. The production of these sulphic radicals may be explained as follows. I use the radical benzyl as an example:—

a. Reaction when Hydrated Sulphuric Acid is used.

$$\left.\begin{array}{ll}\text{Hydrated benzoic acid .} & H,C^7H^5O^2 \\ \text{Hydrated sulphuric acid .} & H,SO^2\end{array}\right\} = \left\{\begin{array}{l}H,C^7H^4SO^3. \\ (H,HO \textit{ set free.})\end{array}\right.$$

b. Reaction when Anhydrous Sulphuric Acid is used.

$$\left.\begin{array}{ll}\text{Hydrated benzoic acid .} & \left\{\begin{array}{l}H,C^7H^5O^2 \\ H,C^7H^5O^2\end{array}\right. \\ \text{Anhydrous sulphuric acid} & S,SO^3\end{array}\right\} = \left\{\begin{array}{l}H,C^7H^4SO^3. \\ H,C^7H^4SO^3. \\ (H,HO \textit{ set free.})\end{array}\right.$$

As an atom of water is thrown off in each case, the proportions of the acting ingredients are regulated by that contingency.

But the sulphic radicals, thus produced, never give monobasic salts agreeing with the formula $H,C^7H^4SO^3$. Formed, as they are, in the presence of an excess of sulphuric acid, they always combine with an atom of that acid, and produce a double salt of the formula:

$$H,C^7H^4SO^3 + HSO^2 = H,H\,;\ C^7H^4S^2O^5.$$

This formula represents the structure of all the salts that contain sulphic radicals. As exhibited by the analytical formula, they are double salts; as exhibited by the synoptical formula they are bibasic salts; and as respects their nomenclature, we have the choice of naming them in accordance with either of these formulæ. I shall give no examples of such salts in this section; because the sulphic radicals will again come under our consideration in the discussion of the Constitution of Conjugated Acids and elsewhere.

IV. Metallic Vice-Radicals.

There are two kinds of metallic vice-radicals:—1st. Amidogen $= ZH^2$, and ammonium ZH^4, are subject to exchange part, or the whole, of their hydrogen for metals, and thus produce compound basic radicals which may be called metallic vice-amidogens and metallic vice-ammoniums. These will come under our consideration in a subsequent section.

2ndly. Many basic compound radicals of the hydrocarbon series exchange part of their hydrogen for metals, and thus produce compound radicals—metallic vice-radicals—of a special character. These are at present scarcely recognised by chemists, but in subsequent sections of this Essay, I trust to be able to satisfy the reader that they actually exist. In the meantime, I shall quote a single example, in order to explain the proposed nomenclature of these metallic vice-radicals.

CH^2Ba represents methyl in which an atom of hydrogen is replaced by an atom of barium. The name proposed for it is *barytic-methyla.*

The Phosphates.

The following diagram exhibits the constitution of the phosphates:

	Graham's Formulæ.[1]	Proposed Formulæ.[2]
No. 1.	KO,PO^5	$= KPO^3.$
2.	KO,KO,PO^5	$= KPO^3 + K^3PO^4 = K^4P^2O^7.$
3.	KO,KO,KO,PO^5	$= KPO^3 + KKO = K^3PO^4.$

No. 1 in this Table is the metaphosphate or monobasic phosphate. No. 2 is the pyrophosphate or bibasic phosphate. No. 3 is the ordinary or tribasic phosphate. The second column represents the formulæ which I am inclined to give to these salts.

According to this view, the metaphosphate is the normal phosphate containing one basic radical and one acid radical, both oxidised = KO,POO. The terbasic phosphate is a compound of the normal phosphate = KO,POO, with a dioxide, or salt on the model of water = H,HO, or M,MO, or M,HO; producing the following double salts:—

Analytical Formulæ.	Synoptical Formulæ.
$MPO^3 + HHO$	$= MHH, PO^4.$
$MPO^3 + MHO$	$= MMH, PO^4.$
$MPO^3 + MMO$	$= MMM, PO^4.$

The synoptical formulæ describe the terbasic phosphate as if it were really a terbasic salt, namely, *a salt in which one acid radical is combined directly with three basic radicals.* I do not admit the truth of that theory. On the contrary, I consider the constitution of the terbasic phosphate to be represented by the analytical formula:—

$$KO,POO + K,KO.$$

It is, namely, a *double salt,* the two components of which have each its basic and its acid radical. When we transpose this analytical formula into the synoptical formula K^3PO^4, we no longer express the true chemical constitution of the salt, but we obtain a formula that is useful in explaining those cases of double decomposition in which the phosphates bear a part. I have already said, and I repeat it, that, in the present state of chemical knowledge, a clear distinction should be made between our *conjectures* respecting the proximate constitution of salts and our mechanical construction of chemical formulæ to be used in the registry and communication of our experience. We have knowledge enough of the transformations which the phosphates undergo, to be able to construct formulæ that can accurately represent and record those transformations; but of the internal constitution of the phosphates *we* KNOW *nothing*. Our analyses prove that in terbasic phosphate of potash, we have potassium, phosphorus, and oxygen. Using Mr. Graham's atomic weights, the atoms are $K^3P^1O^8$. Using the atomic weights that are advocated in this Essay, the atoms are $K^3P^1O^4$. Of the manner in which the oxygen is distributed among the other elements, and in which it is combined with them, we know absolutely nothing. Mr. Graham's groupment of the elements into KO,KO,KO,PO^5, and my groupment of them into $KO,POO + K,KO$, are both *conjectures*: nothing more! It is consequently impossible to give an incontestable, rational formula for the phosphates, and therefore I conclude it to be best to give such a formula as is likely to be most useful in practice, and, as regards the proximate constitution of the salt, to hold my mind at liberty to form opinions as analogies and the light of circumstantial evidence may direct. I give therefore to the terbasic phosphates a terbasic formula, but I believe that the terbasic phosphates are double salts composed of two simple monobasic salts, and agreeing therefore with the doctrine which I am attempting to establish, that every simple salt is a binary compound of two radicals.

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[1] K = 39; P = 31; O = 8.

[2] K = 39; P = 31; O = 16.

The pyrophosphate seems to be a compound of the other two phosphates, atom to atom. Thus: $KPO^3 + K^3PO^4$. There appear also to be other combinations of metaphosphates with terbasic phosphates, in proportions differing from those that constitute the pyrophosphate; such as—

$$\begin{aligned} 4(AgPO^3) + AgAgO &= Ag^4P^2O^7 + 2AgPO^3. \\ 3(AgPO^3) + AgAgO &= Ag^4P^2O^7 + AgPO^3. \\ 10(AgPO^3) + AgAgO &= Ag^4P^2O^7 + 8AgPO^3. \end{aligned}$$

If the pyrophosphates are formulated synoptically as $K^4P^2O^7$, they are made to appear as tetrabasic salts, which notion may, for the reasons which I have just given, be accepted for its mechanical convenience, but is not to be considered as expressing a chemical fact. The proximate constitution of the pyrophosphates, like that of the terbasic phosphates, is absolutely unknown. My *opinion* of it is expressed by the following analytical formula:—

$$(KO,POO + K,KO) + KO,POO.$$

The transformation and reduction of this analytical formula to the synoptical formula $K^4P^2O^7$, is simply with a view to practical or mechanical utility.

The basylic equivalents given in this Essay greatly simplify the formulæ of the phosphates of the compounds which are commonly called sesquioxides. Thus:—

Instead of	We have
$Al^2O^3,3PO^5$.	$AlcSO^3$.
$Fe^2O^3,3PO^5$.	$FecPO^3$.
$Cr^2O^3,3PO^5$.	$CrcPO^3$.
$2Cr^2O^3,3PO^5$.	$CrcPO^3 + Crc^3PO^4$.

By adopting a proper atomic weight for the basylic radical of every sesquioxide, we are freed from the necessity of making their salts triple. In fact, three atoms of phosphoric acid were required in such salts merely because chemists took three atoms of base, instead of one atom, to compose each salt, and by a perverse ingenuity made the three atoms appear to be only one atom, and that one atom of such a kind that three atoms of acid were necessary to neutralise it.

According to the theory which I have endeavoured to explain in this Essay, *there is but one kind of phosphoric acid, and that is monobasic.* The normal phosphate is the metaphosphate, which is composed of one basic radical and one acid radical. The terbasic phosphate is a combination of the normal phosphate with a salt of the formula M,MO, and the bibasic phosphate is a compound of the monobasic with the terbasic phosphates. All other phosphates contain these three varieties variously combined; or with the addition of xHHO, xMHO, or xMMO.

I insist upon this method of accounting for the composition of the three classes of phosphates, because it is the only reasonable manner of replying to these objections to the binary theory of salts which M. Dumas founded expressly upon the constitution of the phosphates. See page 20 of this work. The propositions that the metaphosphates are M,PO^3, that the tribasic phosphates are $M,PO^3 + MMO$; and that the pyrophosphates are $M,PO^3 + M^3PO^4$, are so much in accordance with our knowledge of numerous double salts of similar constitution, that we can admit the theory without much hesitation. But the case is entirely different when we formulate the phosphates expressly as monobasic, bibasic, and tribasic salts, thus:—

M,PO^3 = monobasic.
M^4,P^2O^7 = bibasic.
M^3,PO^4 = tribasic.

According to this diagram, taking the phosphorus and oxygen together, we have before us three totally different kinds of phosphates, those with PO^3, P^2O^7, and PO^4, and we have no longer for adoption the simple case where one and the same acid radical combines with different quantities of the same basic radical. Then again, we have to consider the probability of the occurrence of such combinations between radicals as those which are represented in the diagram by (M + M + M + M) + (P + P) and (M + M + M) + P. A glance at the numerous formulæ of gaseous salts which appear in the preceding pages will show the extreme unlikelihood of the formation of such compounds as these, and will suggest the almost unavoidable conclusion, that phosphoric acid is neither bibasic nor tribasic, but only subject to form those peculiar double salts, that SEEM to be *bibasic* and *tribasic* while considered as compounds of fictitious *acids* and *bases*.

When monobasic phosphoric acid is boiled in water, it is converted into tribasic acid, without passing through the intermediate stage of bibasic acid. That experiment cannot be explained on the acid theory, but it agrees perfectly with the radical theory. The tribasic acid is the result of the direct combination of the monobasic acid with water, atom to atom, $HPO^3 + HHO$. The bibasic acid is a secondary compound that demands the previous formation of the tribasic acid, for it cannot be made by the direct combination of the monobasic acid with water, because it is physically impossible to boil $HPO^3 + HPO^3$ in HHO, and when more HHO is used you produce the tribasic acid. This reaction is consequently in favour of the view that I am advocating of the constitution of the phosphates.

In conclusion, I admit the varieties of phosphates to be as follows:—

	Analytical Formulæ.	Synoptical Formulæ.
Monobasic, or metaphosphate	KPO^3	$= KPO^3$.
Bibasic, or pyrophosphate	$KPO^3 + KPO^3,KKO$	$= K^4P^2O^7$
Tribasic, or common phosphate	$KPO^3 + KKO$	$= K^3PO^4$

The Nomenclature of the phosphates has proved to be difficult upon every theory that has been applied to them. Comprehending many bases, and in diversities of number, the salts require names that are necessarily long, and for that reason subject to be uncouth. No systematic nomenclature can give short names to double, triple, and quadruple salts, without abridgments that must introduce ambiguity with brevity. The nomenclature now proposed is fully equal to the exact expression of the composition indicated by the symbols of the different phosphates, but it does not escape the evils of length and complexity to which all systematic names of the phosphates must ever be liable.

The acid radicals and the oxygen of the three classes of phosphates will in all cases be indicated thus:—

Monobasic, or metaphosphates by PO^3 = Phosphite.
Tribasic, or common phosphates by PO^4 = Phosphote.
Bibasic, or pyrophosphates by P^2O^7 = Phospheneze.

The substantive portion of the names is therefore simple. The difficulty lies in the adjective portion of the name, which must nominate all the basic radicals that are present in each salt.

Examples of Phosphates.

Common Formulæ.	Proposed Formulæ.	Proposed Names.
a. Metaphosphates.		
NaO,PO^5	$NaPO^3$	Natra phosphite.
AgO,PO^5	$AgPO^3$	Argenta phosphite.
$Al^2O^3,3PO^5$	$AlcPO^3$	Alanic phosphite.
$Cr^2O^3,3PO^5$	$CrcPO^3$	Chromic phosphite.
b. Tribasic Phosphates.		
$3KO,PO^5$	K^3PO^4	Potassine phosphote.
$2KO,HO,PO^5$	K^2H,PO^4	Potassen hydra phosphote.
$KO,2HO,PO^5$	KH^2,PO^4	Potassa hydren phosphote.
$3NaO, PO^5 + 12Aq$	$Na^3PO^4 + Aq^6$	Natrine phosphote aquaze.
$3AgO,PO^5$	Ag^3PO^4	Argentine phosphote.
$NH^4O,NaO,HO,PO^5 + 8Aq.$	$Na,NH^4,H,PO^4 + Aq^4$.	Natra ammona hydra phosphote, aquote.
$2HO,C^4H^5O,PO^5$.	$C^2H^5,H^2; PO^4$.	Ethyla hydren phosphote.
$HO,2C^4H^5O,PO^5$.	$(C^2H^5),^2H; PO^4$	Ethylen hydra phosphote.
$3C^4H^5O,PO^5$	$(C^2H^5)^3PO^4$	Ethyline phosphote.
c. Pyrophosphates.		
$2C^4H^5O,PO^5$	$(C^2H^5)^4P^2O^7$	Ethylone phospheneze.
$2KO,PO^5$	$K^4P^2O^7$	Potassone phospheneze.
$2Cr^2O^3,3PO^5$	$Crc^4P^2O^7$	Cromonic phospheneze.

The above names give a necessary, and a very unfavourable, example the application of the proposed nomenclature to compound salts. The critic will instantly perceive that "microcosmic salt" is a much shorter term than "natra ammona hydra phosphote aquote; and that "ordinary phosphate of soda" (Gmelin's name) is far easier than "natrine phosphote aquaze;" but then, the short and easy names do not express the constitution of the compounds, and in regard to such complex substances it will perhaps be ever impossible to find words that will accurately state their composition, and yet be short and easy. Any systematic nomenclature must be judged of by its general applicability and not by its failure in a few special and non-important instances.

The Phosphites.

According to the researches of Railton[1] and Williamson,[2] a phosphite requires the following formula—

$$M,M,M;\ PO^3.$$

Comparing this constitution with that of a metaphosphate = MPO^3, we observe the striking peculiarity, that with the same acid radical and the same amount of oxygen in each salt, we have in the metaphosphate *one* basic radical, and in the phosphite *three* basic radicals. At first sight, such a result appears improbable; but a little investigation removes the apparent difficulty. The constitution of the metaphosphate is

$$MO + POO.$$

That of the phosphite is—

$$MO,PO + M,MO.$$

Namely, it is a double salt, where $MO,PO = MPO^2$ is of the same form of constitution as the oxalates and sulphates, and M,MO of the same constitution as water H,HO. These two salts combine to form terbasic phosphite, just as MPO^3 and MMO combine to form a terbasic phosphate. But the normal salt MPO^2 is unknown.

The following are examples of phosphites :—

$Ba,C^2H^5,C^2H^5;\ PO^3$	Baryta ethylen phosphite.
$Ba,Ba,C^2H^5;\ PO^3$	Baryten ethyla phosphite.
$Ba,Ba,H;\ PO^3$	Baryten hydra phosphite.
$C^5H^{11},C^5H^{11},C^5H^{11};\ PO^3$	Amyline phosphite.
$C^2H^5,C^2H^5,C^2H^5;\ PO^3$	Ethyline phosphite.
$Pb,C^2H^5,H;\ PO^3$	Plumba ethyla hydra phosphite.
$Ba,C^2H^5,H;\ PO^3$	Baryta ethyla hydra phosphite.
$Sn,Sn,H;\ PO^3$	Stenous hydra phosphite.

No inorganic normal phosphite contains three atoms of metal. They have all two atoms of metal and one atom of hydrogen. Rose considers them to be bibasic, but always containing water of cystallization; and Wurtz has attempted to prove that they are bibasic, with a *compound acid radical* consisting of PH. That theory seemed to be probable when we judged from the composition of the mineral phosphites, in all of which we find H^1; but Railton's discovery of the salts—

$$Ba,C^2H^5,C^2H^5;\ PO^3.$$
$$Ba,Ba,C^2H^5;\ PO^3.$$
$$C^2H^5,C^2H^5,C^2H^5;\ PO^3.$$

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[1] Quarterly Journal of the Chemical Society (1854), VII. 216.

[2] Proceedings of the Royal Society (1854), VII. 131.

seems to overturn Wurtz's theory. Yet it is remarkable that Railton tried in vain to produce the salt—

$$Ba,Ba,Ba;\ PO^3,$$

and that in those cases of inorganic basic salts, where there is present a great excess of metal, there is also always present as much hydrogen or water as gives at least possibility to the theory of the presence of the compound radical PH in all inorganic phosphites.

The Hypophosphites.

The composition of the hypophosphites is uncertain. Many of the inorganic hypophosphites seem to be—

$$MPO + H,HO$$
$$\text{equal to } M,H,H;\ PO^2.$$

But they cannot be deprived of this hydrogen or water, and the normal salt = MPO is unknown. Wurtz has suggested that they contain a compound acid radical = PH^2, and that the proper formulæ of the salts is—

$$M,PH^2O^2.$$

On the other hand, Kane has pointed out the existence of a salt containing hypophosphite of barytes and acetone, equal to

$$Ba,CH^3,C^2H^3;\ PO^2 = \text{Baryta methyla acetyla phosphete.}$$

and a similar salt containing soda—

$$Na,CH^3,C^2H^3;\ PO^2 = \text{Natra methyla acetyla phosphete.}$$

If, on this ground, we admit the hypophosphites to be tribasic, we have still the difficulty of accounting for the circumstance that the three basic radicals of the inorganic salts are always MHH, and never MMM.

The Sulphates.

According to the radical theory, the composition of hydrated sulphuric acid is as follows:—

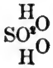
Analytical Formula.	Synoptical Formula.
HO,SO.	HSO^2

Where H = 1, S = 16, O = 16.

According to M. Gerhardt, sulphuric acid is composed thus:[1]

$$O^2\left\{\begin{matrix}SO^2\\H^2\end{matrix}\right.$$

According to Professor Williamson, sulphuric acid is composed thus:[2]



$$\begin{matrix}H\\ O\\ SO^2\\ O\\ H\end{matrix}$$

where H = 1, S = 32, O = 16.

According to the radical theory, sulphuric acid is monobasic, that is to say, it contains one atom of hydrogen replaceable by a metal. According to Messrs. Gerhardt and Williamson, sulphuric acid is bibasic, that is to say, it contains two atoms of hydrogen which are both or either replaceable by metals. The compound which on the theory of Gerhardt and Williamson is a single *bibasic sulphate*, is, on the radical theory, a *double salt* composed of *two monobasic sulphates*. These theories are consequently antagonistic. I believe that the radical theory is the true one, and I shall endeavour to show that the arguments by which the bibasic theory is advocated are such as cannot command our assent.

M. Gerhardt's *first and main argument*[3] depends upon the atomic measure of the gaseous sulphates. He points out that when you examine a gaseous salt, of a kind that is admitted to be monobasic, such as an acetate or a benzoate, you find that two volumes of it contain one basic radical, but that when you examine a gaseous sulphate, you find that two volumes of it contain two basic radicals; whence he infers, that sulphuric acid is bibasic.

This argument is worthless, because it leaves out of consideration the fact, that the radical sulphur in the gaseous sulphates measures nothing. The consequence of that property is, that a gaseous sulphate is complete in one volume, and that if you examine two volumes of the gas, you find two basic radicals because you operate upon two complete sulphates. This attempt to prove that sulphates are bibasic is consequently abortive.

M. Gerhardt's *second argument* depends upon the properties of the gases that contain chlorine with sulphur. Thus he points out that—

$$2\text{ volumes of}\left\{\begin{matrix}\text{Chloride of acetyle contain } Cl,C^2H^3O.\\ \text{Chloride of sulphuryle contain } Cl^2,SO^2.\end{matrix}\right.$$

From which, as before, he concludes that sulphur is bibasic, and acetyle monobasic. But this argument rests on no better foundation than the former. The oxychloride of sulphur (chlorosulphuric acid) SClO, or ClSO, is complete in one volume, because S and O measure nothing;

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[1] Traité de Chimie Organique (1856), tom. iv. p. 642.

[2] Quarterly Journal of the Chemical Society (1854), VII. 182.

[3] Vide the Traité de Chimie already cited.

and in two volumes of vapour you have two complete salts, and therefore two radicals of each kind. This and the preceding argument have been so fully discussed at pages 98, 102, and 113, that further criticism is needless.

Third argument.—"Whereas monobasic acids give but one compound ether, sulphuric acid gives two, one neutral and one acid. Whereas monobasic acids give but one amide, sulphuric acid gives several."

My reply to this argument is, that the compounds in question depend upon the property which sulphur possesses of forming numerous compound salts, not only double, but triple, fourfold, fivefold, and varieties still more complex. The property of producing compound salts is quite a different thing from the property of *bibasicity*, meaning by the latter term the power possessed by *one acid radical* of combining with *two basic radicals*. This is the property which, in my opinion, does not belong to sulphuric acid; and no mere enumeration of the ethers, the amides, and other double salts, which sulphuric acid unquestionably does form, can affect the point at issue, which stated in plain terms, is the assertion that *two basic radicals* can combine with *one atom of oxidised sulphur* to form a sulphate. This is the point that I deny, and M. Gerhardt only evades the real question, when he doubles the atomic weight of sulphur, and when he adduces double salts, namely, *pairs of sulphates*, containing ethyl, amidogen, and other bases, to prove that one sulphate contains two basic radicals.

Fourth argument.—"If we determine what are the smallest possible quantities of the radical acetyl and the radical sulphuryl which occasion chemical metamorphoses, we find that these radicals are C^2H^3O equivalent to H, and SO^2 equivalent to H^2. This naturally leads us to represent the molecule of acetic acid as *monatomic*, and the molecule of sulphuric acid as *biatomic*."—Traité, iv. p. 643.

Monatomic, in Gerhardt's language, signifies "derived from one atom of water;" and *biatomic* signifies "derived from two atoms of water." The former has one replacable atom of basic hydrogen, the latter has two such atoms. The "sulphuryl" referred to in this argument as $SO^2 = H^2$, contains 32 parts of sulphur, and is therefore what I should call $SO \times 2$. It is equivalent to H^2 simply because it contains S^2. The oxygen has nothing to do with the question of basicity. Here M. Gerhardt first assumes that two atoms of sulphur are one atom, and then finding that this so-called one atom is equivalent to two basic radicals, he calls it bibasic. The question at issue turns, therefore, upon the mere matter of fact whether 32 parts of sulphur is the "smallest possible quantity" which has the power of chemical action. To dispose of that question, I shall show in this book that all the classes of salts of which sulphur is a constituent can be simply and effectively represented by formulæ in which S^1 will in all cases signify 16, and not 32, parts of sulphur. If I do that, it will show that the assumption of 32 is improper, and, as a consequence, that this fourth argument is fallacious. I may, moreover, point out the remarkable circumstance that the compounds that are commonly called sulphides or sulphurets, all contain one atom each of M and S, where M signifies one metallic radical or one atom of a hydrocarbon radical, and S equals 16 parts of sulphur. The consequence of this relationship is, that when M. Gerhardt treats of these compounds, instead of using the simple formula MS, he is forced to use the bibasic formula $S\left\{\begin{matrix}M\\M\end{matrix}\right.$; that is to say, he is forced to make the sulphides all double, because he has doubled the atom of sulphur. See his account of the sulphurets, *Traité de Chimie Organique*, tom. iv. p. 700.

Fifth and final argument.—This argument is founded on the reaction of nitric and sulphuric acids with benzoic acid—reactions resulting in the production of nitrobenzoic acid and sulphobenzoic acid. I have discussed this subject under the heads of sulphic vice-radicals and conjugated acids, to which sections I must ask the reader to refer for intimate details. In this place I will briefly quote the results. Benzyl and nitrogen produce a deputy or vice-radical, in which the primary radical benzyl exchanges an atom of hydrogen for an atom of nitrogen, and this altered radical produces a salt, or, if you please to call it so, an acid, of this form :—

$$H,C^7H^4ZO^4 = \text{Nitrobenzoic acid},$$

which shows one replaceable atom of basic hydrogen. Benzyl and sulphur also produce a vice-radical, in which benzyl exchanges an atom of hydrogen for an atom of sulphur, and this vice-radical produces a double salt, or double acid, of the form—

$$H,C^7H^4SO^3 + H,SO^4 = \text{Sulphobenzoic acid},$$

where there are two replaceable atoms of basic hydrogen.

The main facts to be observed here are, that nitric acid, which rarely forms double salts, true to its ordinary character, forms no double salt with nitrobenzoic acid; whereas sulphuric acid, which has an extraordinary tendency to produce double salts, particularly in combination with organic radicals, true to its ordinary character, forms a double salt with the sulphobenzoic acid. The nitrobenzoic acid is monobasic, because it contains one acid radical. The sulphobenzoic acid is bibasic, because it contains two acid radicals, namely, sulphic benzyl and normal sulphur. But M. Gerhardt insists upon it that sulphobenzoic acid is bibasic, because it contains *one acid radical*, the one acid radical containing, according to him, one atom of sulphur, that one atom of sulphur weighing 32, and the salt being bibasic, in consequence of the presence of that one heavy atom of sulphur. But M. Gerhardt goes a great deal too fast. His argument proves nothing, unless you admit that 32 parts is one atom of sulphur. This is the grand point which he *assumes* to be true, which, however, it is the great object of his arguments *to prove* to be true, and to do which they all signally fail. Yet he seems to have satisfied himself that the force of his arguments amounted to demonstration.

"Mr. Graham," he says,[1] "was the first to admit the existence of polybasic acids in his work On the Modifications of Phosphoric Acid, formulating them according to the ancient dualistic theory. A German chemist [Liebig] sought to apply the same ideas to certain organic acids; but this chemist depending, like his predecessor, only on the composition of the salts, was unable to fix precisely the characters of the acids endowed with different degrees of basicity. I consider that I have better defined these characters by resting on the properties of corresponding volatile bodies (the chlorides and compound ethers). The law of the saturation of conjugated acids has, above all, permitted me to put in evidence the well-marked differences which exist between certain mineral and organic acids in respect of their basicity."

I have gone over M. Gerhardt's arguments in detail, because he admits that "the whole question of polybasic acids" is comprised in those arguments. The arguments appear, however, to me, to be eminently futile; and unless other admirers of polybasic acids have something stronger to say, I fancy that modern chemists must content themselves, as their grandfathers did, with the possession of monobasic acids.

Let us next listen to Professor WILLIAMSON;—"Chemists," he says,[2] "have long been aware of the fact, that some acids unite with bases in one proportion only, others in two or more proportions. Thus a given quantity of nitric acid forms, with what is termed its equivalent of potash, a definite nitrate of potash; if less than this equivalent quantity of potash were added to the nitric acid, the product would be a mechanical mixture of the same nitrate of potash with uncombined nitric acid; if more than the equivalent of potash were added, the excess of alkali would remain uncombined. Sulphuric acid, on the other hand, is capable of forming two compounds with potash, and it depends upon the proportions in which the two substances are brought together, whether the neutral or acid sulphate is formed.

"The number of compounds which an acid forms with one base is now considered as indicating its atomic weight. The weights of sulphuric and nitric acids, which are respectively susceptible of neutralising the same quantity of potash, are termed *equivalent*, but these are by no means the same as their *atomic* weights. Sixty-three parts of nitric acid (nitrate of water) contain the same quantity of hydrogen as forty-five [forty-nine?] parts of sulphuric acid, and when they are neutralised by potash the whole of this hydrogen is removed, and replaced by potassium; and if neither of the acids would combine in any other proportion with potash, their atomic weights would be the same as their equivalent weights. But sulphuric acid also forms a potash-compound in which half of its hydrogen is replaced by potassium, the other half remaining in the compound, whereas the smallest particles of nitric acid either exchange the whole or none of their hydrogen for potassium.

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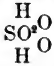
[1] Traité de Chimie Organique, tom. iv. p. 646.

[2] Proceedings of the Royal Society, VII. 11; and Quarterly Journal of the Chemical Society (1855), VII. 180.

"This fact is expressed in the simplest possible manner by the statement that the smallest indivisible particles of sulphuric acid contain two atoms of hydrogen, whilst those of nitric acid only contain one. Thus it is, that whereas the equivalent weights of the two acids are the quantities which contain the same amount of basic hydrogen, their atomic weights must be in the proportion of two equivalents of sulphuric to one of nitric acid. The simplest expression for one atom of nitric acid being empirically NO^3H, we shall accordingly represent an atom of sulphuric acid by the formula SO^4H^2. In like manner an atom of common phosphoric acid, being tribasic, is expressed empirically by the formula PO^4H^3. The labours of Messrs. Laurent and Gerhardt greatly contributed to the establishment of these results, *which are uncontroverted.*"

I will endeavour to do away with this last reproach by offering a little controversion.

I hold that the distinction drawn by Professor Williamson between the *equivalent* and the *atom* of sulphuric acid is unnecessary and injurious; that the smallest indivisible particle of sulphuric acid contains only one atom of hydrogen, not two atoms; that the simplest expression for an atom of sulphuric acid is HSO^2, not  $SO^2\begin{matrix}\overset{\text{H}}{\text{O}}\\ \underset{\text{H}}{\text{O}}\end{matrix}$; that sulphuric acid is monobasic, not bibasic; and that the atom of sulphur weighs only 16, and not 32. These opinions are supported by the following reasons:—

Every atom of sulphuric acid contains one atom of sulphur and one atom of hydrogen. These atoms are perfectly equivalent to one another, and either of them can be replaced by one atom, that is to say, by one equivalent, of another radical. The argument, that you can take a certain quantity of hydrated sulphuric acid, and replace half its hydrogen by one radical and the other half by another radical, and thus produce *a bibasic sulphate*, is a good argument as far as it goes; but when it is offered, as Professor Williamson offers it, as a conclusive argument embracing the whole question, it is a fallacy of that class, where what is stated truly of *a part* of a thing is assumed as being truly stated of *the whole* of a thing; for you can also take a quantity of hydrated sulphuric acid and replace its hydrogen by one, or three, or four, or five, or six, or seven, or eight different radicals, and procure crystallised sulphates that contain all or any number of these radicals, and which, therefore, according to Professor Williamson's argument, ought to be called monobasic, tribasic, tetrabasic, pentabasic, hexabasic, heptabasic, and octabasic sulphates.

Let us look at the evidence that shows, from experimental grounds, what is the constitution of the sulphates.

In the following Table $H = 1$, $S = 16$, $O = 16$.

Monobasic Sulphates—formed from H,SO^2.

HSO^2	. . . Oil of vitriol.
KSO^2	. . . Sulphate of potash,

and perhaps nine-tenths of all the sulphates that are known to exist.

Bibasic Sulphates—formed from H^2,S^2O^4.

K,H; S^2O^4.	Mg,Alc; S^2O^4.	K,Cr; S^2O^4.	[1]
K,G; S^2O^4.	Na,Mn; S^2O^4.	Am,Fe; S^2O^4.	

Tribasic Sulphates—formed from H^3,S^3O^6.

Fe,Fe,Fec; S^3O^6.	[1]	Fe,Fe,H; S^3O^6.	[1]
Ba,Ba,Ca; S^3O^6.		Fe,Fec,Fec; S^3O^6.	
K,K,H; S^3O^6.		Mg,Zn,Mn; S^3O^6.	[2]

Tetrabasic Sulphates—formed from H^4,S^4O^8.

Am,Am,Am,H; S^4O^8.	[1]	Zn,Alc,Alc,Alc; S^4O^8.	[1]
Alc,Alc,Alc,H; S^4O^8.		K,Crc,Crc,Crc; S^4O^8.	
K,Fec,Fec,Fec; S^4O^8.		Na,Crc,Crc,Crc; S^4O^8.	
Zn,Zn,Zn,H; S^4O^8.		Am,Crc,Crc,Crc; S^4O^8.	
K,Alc,Alc,Alc; S^4O^8.		Fe,Fe,Fe,H; S^4O^8.	
Mg,Co,Co,Co; S^4O^8.		Fec,Fec,Fec,H; S^4O^8.	
Am,Am,Zn,Fe; S^4O^8.		K,Cuc,Cuc,Cuc; S^4O^8.	
Am,Am,Mg,Cuc; S^4O^8.		K,K,Ni,Cuc; S^4O^8.	
Am,Am,Cuc,Fe; S^4O^8.	[2]	Am,Am,Zn,Cuc; S^4O^8.	[2]
K,K,Cuc,Fe; S^4O^8.		Am,Am,Zn,Fe; S^4O^8.	
Am,Am,Mg,Cuc; S^4O^8.		K,K,Co,Cuc; S^4O^8.	
K,K,Mg,Cuc; S^4O^8.		K,K,Mn,Cuc; S^4O^8.	

Pentabasic Sulphates—formed from H^5,S^5O^{10}.

Cuc,Cuc,Cuc,Cuc,H; S^5O^{10}.[1]

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[1] Laurent, Chemical Method, pages 116–123.

[2] Vohl, Liebig's Annalen der Chemie, April, 1855.

Hexabasic Sulphates—formed from H^6,S^6O^{12}.

K,K,K,Mg,Mn,Cuc; S^6O^{12}. [2]

[There are several salts agreeing with this formula.]

Heptabasic Sulphates—formed from H^7,S^7O^{14}.

K,K,K,K,K,H,H; S^7O^{14}. [1]

Octabasic Sulphates—formed from H^8,S^8O^{16}.

$$\left.\begin{array}{ll} \mathrm{K,K,K,K,Mg,Zn,Co,Cuc;} & \mathrm{S^8O^{16}} \\ \mathrm{K,K,Alc,Alc,Alc,Crc,Crc,Crc;} & \mathrm{S^8O^{16}} \\ \mathrm{Am,Am,Alc,Alc,Alc,Crc,Crc,Crc;} & \mathrm{S^8O^{16}} \end{array}\right\} ^{2}$$

With these examples before us, we can estimate the force of Professor Williamson's argument. He pitches upon the second group in the above Table, and he says, "Here we have a quantity of sulphuric acid which we may call two equivalents, because it contains two replaceable atoms of hydrogen; but we can replace half of its hydrogen by potassium, the other half remaining in the compound. We thus procure a complete crystallizable sulphate—*one* sulphate—containing, therefore, *one atom* of sulphuric acid and one atom of sulphur, but having two bases, being consequently bibasic, and agreeing with the formula SO^4H^2."

Change the ground a little, and apply this argument to the *octabasic sulphate*. "We have here," we may say, "a quantity of sulphuric acid which represents eight equivalents, because it contains eight replaceable atoms of hydrogen. We replace these atoms of hydrogen by eight atoms of different metals, and we produce a complete neutral crystallisable salt, whose composition is stated in the simplest possible manner by the formula

K,K,K,K,Mg,Zn,Co,Cuc; S^8O^{16};

whence it follows, that this is *one* sulphate—*one atom* of a sulphate—containing one atom of sulphuric acid, and therefore one atom of sulphur; and, consequently, sulphuric acid is proved to be octabasic, and the atom of sulphur is proved to weigh 128 ($= 16 \times 8$)."

This argument applies equally well to every one of the eight groups of sulphates arranged in the above table, and consequently proves so much, that it proves nothing at all. It would be absurd to admit that an acid is proved to be *bibasic* by an argument which is equally powerful in proving it to be octabasic, heptabasic, pentabasic, tribasic, &c., &c., &c.

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[1] See p. 150. [2] Ibid.

I proceed, however, to adduce the *experimental evidence* by means of which Professor Williamson attempts to establish his theory. I quote from the journal previously referred to:—

"In some papers published in the Journal of the Chemical Society two or three years ago, I endeavoured to show that the constitution of salts may be reduced to the type of water; that acids and bases, being truly acid salts and basic salts, are perfectly conformable to the same principle; and that, amongst other things, the difference between monobasic and bibasic acids, &c., admits of a simple and easy explanation by it. The leading propositions in those papers have been adopted by several eminent chemists in this country and in France; and M. Gerhardt speedily enriched science with a series of brilliant and striking illustrations of their truth. As regards the constitution of bibasic acids, M. Gerhardt's results were, however, at variance with that theory; and he was led to represent them by formulæ equally inconsistent with his own previous views on the subject. I believe that this discrepancy is satisfactorily removed by the facts I have the honour of submitting to the consideration of the Society.

"An atom of nitric acid, being eminently monobasic, is, as we have already shown, represented in the monobasic type water $\begin{matrix}H\\H\end{matrix}O$ by the formula $\begin{matrix}(NO^2)\\H\end{matrix}O$, in which peroxide of nitrogen (NO^2) replaces one atom of hydrogen. In like manner, hydrate of potash $\left(\begin{matrix}H\\K\end{matrix}O\right)$ is obtained by replacing one atom of hydrogen in the type by its equivalent of potassium; and nitrate of potash $\left(\begin{matrix}NO_2\\K\end{matrix}O\right)$ by a simultaneous substitution of *one* atom of hydrogen by protoxide of nitrogen and the *other* by potassium.

"Sulphuric acid is formed from two atoms of—

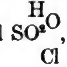
water $\begin{matrix}H\\H\end{matrix}O \atop \begin{matrix}H\\H\end{matrix}O$; one of hydrogen from each is removed, and the two replaced by the indivisible radical SO^2. The series—

Sulphuric Acid.	Acid Sulphate of Potash.	Neutral Sulphate of Potash.
$\begin{matrix}H & O\\SO^2 & \\H & O\end{matrix}$	$\begin{matrix}H & O\\SO^2 & \\K & O\end{matrix}$	$\begin{matrix}K & O\\SO^2 & \\K & O\end{matrix}$

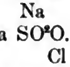
explains itself.

"Chemists have long known how to remove the basylous constituents H, K, &c. of these salts, and to replace them by others; but it is only recently that they have learnt to remove the chlorous radicals SO^2, NO^2, &c. in a similar manner. To obtain the chloride of potassium from its sulphate, it is sufficient to bring the latter into liquid contact with chloride of barium; but the same reagent would be powerless for the preparation of the chlorides of the radicals SO^2 or NO^2.

"M. Cahours has shown us a reagent (the pentachloride of phosphorus) which is capable of forming from a great number of monobasic acids the chlorides of the acid radicals. Whilst extending our knowledge of the action of the body on monobasic and organic acids, and preparing numerous compounds of their radicals with one atom of chlorine, M. Gerhardt examined also the nature of its action upon bibasic acids and their compounds; and states that it consists of two successive phases—first, the liberation of the anhydrous acid; secondly, the substitution of two atoms of chlorine for one of oxygen in that anhydrous acid. These facts, if correct, would be unfavourable to the above view of the constitution of sulphuric and other bibasic acids; and M. Gerhardt adopted accordingly the old formulæ, representing in their composition an atom of water ready-formed, SO^3H^2O.

"Confining my remarks for the present to the case of sulphuric acid, whose decomposition is doubtless typical of that of other bibasic acids, I may state as the result of numerous experiments with the most varied proportions of pentachloride and acid, performed on a scale of considerable magnitude, that the first action of the pentachloride consists in removing one atom of hydrogen and one of oxygen (empirically, peroxide of hydrogen) from the acid, putting in an atom of chlorine in their place, and forming the compound  $SO^2\begin{array}{l}\overset{H}{}O\\ Cl\end{array}$, which is strictly intermediate between the hydrated acid and the final product SO^2Cl^2 formed by a repetition of the same process of substitution of chlorine for peroxide of hydrogen. The existence and formation of this body, which we may call chloro-hydrated sulphuric acid, furnishes the most direct evidence of the truth of the notion, that the bibasic character of sulphuric acid is owing to the fact of one atom of its radical SO^2 replacing or (to use the customary expression) being equivalent to two atoms of hydrogen. Had this radical been divisible like an equivalent quantity of a monobasic acid, we should have obtained a *mixture*, not a *compound*, of the chloride with the hydrate—or, at least, the products of decomposition of that mixture.

"Chloro-hydrated sulphuric acid boils at 145° cent., distilling without decomposition. The intensity of its action upon water varies according to the manner in which the two bodies are brought together. When poured rapidly into a large quantity of cold water, a portion of it sinks to the bottom, and only gradually dissolves as a mixture of hydrochloric and sulphuric acids. When a small quantity of water is added to the compound, the same decomposition takes place with explosive violence. The acid dissolves chloride of sodium on the application of a gentle heat, with evolution of hydrochloric acid, giving rise to a compound of the formula



$\overset{Na}{\underset{Cl}{SO^2O}}$."

I have quoted Professor Williamson's entire argument, because I agree with him, that sulphuric acid is typical of other bibasic acids, so that if he fails to establish the bibasic nature of sulphuric acid, the failure extends to bibasic acids in general. My conviction is, that his failure in this point is complete.

Throughout his argument, Professor Williamson *assumes*, but never *proves*, that the atom of sulphur weighs 32 and not 16. If you admit this assumption as a truth, you virtually admit that the smallest possible quantity of sulphuric acid, being that which contains one atom of sulphur, and therefore that which contains 32 parts of sulphur, is consequently that which contains the equivalent of two atoms of hydrogen. The admission, then, that the atomic weight of sulphur is 32, is practically the admission that sulphuric acid is bibasic. This, however, is the entire question. I ask, therefore, that Dr. Williamson should *prove* this point, and not *assume it to be true without proof;* as he has done in the Paper from which I quote.

I shall now show that his facts all agree with the notion, that the atom of sulphur weighs 16, and that sulphuric acid is monobasic.

First action of the pentachloride. A quantity of hydrated sulphuric acid which contains H^2, gives off HO and takes up Cl. My interpretation of the experiment is as follows:—

$$\begin{matrix}HSO^2\\HSO^2\end{matrix} + Cl = \begin{matrix}ClSO\\HSO^2\end{matrix} + HO.$$

Namely, one atom of monobasic hydrated sulphuric acid = HSO^2 or HO,SO, is converted into ClSO, which combines with another atom of monobasic hydrated sulphuric acid, and produces the double salt $ClSO + HSO^2$, or $H,Cl; S^2O^3$. This salt has a constitution exactly similar to that of a bisulphite, and it is monobasic, that is to say, it has one replaceable atom of hydrogen, which, as Dr. Williamson has proved, can be replaced by sodium, so as to produce a neutral salt, representable by the formula $Na,Cl; S^2O^3$, or $ClSO + NaSO^2$. When treated with water, the double salt $ClSO + HSO^2$ produces hydrochloric and sulphuric acids. Thus:—

$$H,HO + Cl,SO + HSO^2 = HCl + HSO^2 + HSO^2.$$

Final product of the action of the pentachloride. All the sulphuric acid is converted into ClSO; namely—

$$\text{HO,SO} + \text{Cl} = \text{HO} + \text{ClSO}.$$
$$\text{HO,SO} + \text{Cl} = \text{HO} + \text{ClSO}.$$

Dr. Williamson writes this final product SO^2Cl^2, but that is merely because he *doubles* the atomic weight of sulphur; otherwise, he must write it $S^2O^2Cl^2 = SOCl$. This compound is the chlorosulphuric acid referred to at pages 56 and 102 of this work, as a gas having the atomic measure of one volume. Dr. Williamson shows us that it has the faculty of combining with hydrated sulphuric acid, and Professor Rose had previously shown that it combines also with anhydrous sulphuric acid. See page 63.

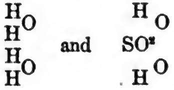
M. Gerhardt's experiment, if it is correct, which Dr. Williamson seems to deny, may also be explained, as indeed he admits, on the notion that sulphuric acid is monobasic. Two atoms of the hydrated sulphuric acid yield one atom of water and one of anhydrous sulphuric acid:—

$$\text{HO,SO} + \text{HO,SO} = \text{H,HO} + \text{S,SOOO}.$$

If we substitute, in this last product, two atoms of chlorine for one atom of oxygen, we have SSClClOO, which, being divisible by two, yields SClO or ClSO.

Here we have all the transformations that occur in the cited experiments—all the tangible facts—duly accounted for on the supposition that S weighs 16, and that sulphuric acid is monobasic; and these results are expressed in formulæ and equations that are of extreme simplicity. Why are we to renounce an easy and satisfactory system, and jump, without necessity and without a shadow of proof, to the various conclusions, that the atom of sulphur weighs 32; that an atom is equal to two equivalents; that sulphuric acid is bibasic; that its smallest indivisible particle contains two atoms of hydrogen; that it is formed from two atoms of water; that all bibasic acids are formed from two atoms of water; and that on the model of one, or two, or more atoms of water, all salts whatever are formed? For my part, I oppose these conclusions with a very decided negative.

I do not know whether Professor Williamson attributes any logical force to the positions given to the symbols in the scattered formulæ by which the constitution of the so-called bibasic sulphates on the model of water are depicted. With what relative degrees of intensity are the respective members of the following compounds combined with one another?



$$\begin{matrix}\begin{matrix}H\\H\end{matrix}O\\\begin{matrix}H\\H\end{matrix}O\end{matrix}\qquad\text{and}\qquad\begin{matrix}H & O\\SO^2 & \\H & O\end{matrix}$$

If, in the single atom of water, O is combined with *equal intensity* to each of the two atoms of H, then SO^2 which replaces H + H, must possess the same combining force as H + H do collectively. But in that case S first of all monopolises O^2 entirely, and then takes up half of each of the other two atoms of O. So that, in fact, in an atom of hydrated bibasic sulphuric acid, S^1 exercises a combining power over 75 per cent. of the oxygen, and the remaining HH, a combining power over 25 per cent. I am at a loss to perceive in what respect this final result differs from the old theory, that hydrated sulphuric acid consists of anhydrous acid = SO^3 plus water = H^2O. We have merely the old system of acids and bases reproduced in another form. An old friend is presented to us with a new face. There appears to be no practical advantage obtainable by departing from the old symbols, if we are to retain the old ideas. On the radical theory, the notion that the oxygen of a sulphate is divided between the basic radical and the acid radical in the unequal proportions of 75 to 25, is repudiated. Without that repudiation, distinctly agreed to, we had better retain the old formula.

NOMENCLATURE OF THE SULPHATES.

		Proposed Names.
Hydrated sulphuric acid	H,SO^2	Hydra sulphete.
[Anhydrous sulphuric acid	S,SO^3	Sulpha sulphite.]
Sulphate of potash	K,SO^2	Potassa sulphete.
Protosulphate of iron	Fe,SO^2	Ferrous sulphete.
Persulphate of iron	Fec,SO^2	Ferric sulphete.
Bisulphate of potash	$K,H; S^2O^4$	Potassa hydra sulphenote.
,, ,,	or $K,H; 2SO^2$	Potassa hydra bisulphete.
A tribasic sulphate	$Ba^2,H; 3SO^2$	Baryten hydra trisulphete.

It is immaterial whether the double sulphates (bisulphates) are called sulphenote or bisulphete, but all sulphates of a more complex constitution will be most conveniently named if called *tri*-sulphete, *tetra-*, *penta-*, *hexa-*, *hepta-*, or *octa*-sulphete; the bases being particularised in the commencement of the name. It is evident, however, that systematic names for such complex compounds as octasulphates will never come into use. If ever any salt of this description should come to be of importance in the arts, it will immediately acquire a trivial name, just as the tetrasulphate of potash and alumina is at present commonly designated by the short word ALUM.

The Polythionic Acids. The Many-Sulphured Acids.

The term *polythionic acids* has been applied to a series of oxidised acids of sulphur which are said to be distinguished by the property of containing more than one atom of sulphur. They are as follows:—

THE ANHYDROUS ACIDS.		THE METALLIC SALTS.	
All of which are hypothetical.		*All considered to be monobasic.*	
Pentathionic acid	S^5O^5	Pentathionate	MO,S^5O^5
Tetrathionic acid	S^4O^5	Tetrathionate	MO,S^4O^5
Trithionic acid	S^3O^5	Trithionate	MO,S^3O^5
Hyposulphuric acid Dithionic acid	S^2O^5	Hyposulphate	MO,S^2O^5
Hyposulphurous acid Dithionous acid	S^2O^2	Hyposulphite	MO,S^2O^2.

The value of the symbols in the above Table is S = 16, O = 8. If I raise O to 16, and write synoptical formulæ of the salts in accordance with the radical theory, they come out as follows:—

Pentathionate = M,S^5O^3
Tetrathionate = M,S^4O^3
Trithionate = M,S^3O^3
Hyposulphate = M,S^2O^3
Hyposulphite = M^2,S^4O^3

I am obliged to double the formula of the hyposulphite, because the three atoms of oxygen cannot, like the six atoms in the other examples, be divided by 2.

This Table includes all the commonly-received oxidised salts of sulphur, except the sulphates and the sulphites. These two are excluded on the ground that they both contain only one atom of sulphur. That reason is valid for the sulphates, but not for the sulphites. The following is the formula by which a sulphite is usually represented:—

$$MO,SO^2, \text{ where } O = 8.$$

Performing the same operation upon this salt as upon the hyposulphite, namely, doubling the atoms, making O = 16, and throwing the symbols into a synoptical formula, the sulphite becomes M^2,S^2O^3. This formula, added to those in the above Table, completes the series of the so-called POLYTHIONATES.

I have, in the course of this Essay, pointed it out as being generally a fact, and I have laid much stress upon that fact as an important element in the radical theory, that every salt contains two radicals, and only two; one positive radical and one negative radical; that this is true whether the salt contains oxygen or no oxygen; and that deviations from this general fact only occur when a salt (already containing two radicals) combines with another positive radical, as in the case of the carbonates = $MO,CO + MO$, or with another negative radical, as in the case of the hyposulphates = $MO,SO + SO$, to form bibasic or biacid salts of a peculiar and very definite character. See page 27, double salts, Classes 5 and 6.

But, as if in contradiction to these facts, or, if you prefer the expression, to these *opinions*, we have in the formulæ that profess to show the composition of the polythionates, a statement that one basic radical can combine, not only with one atom of sulphur, but with two, three, four, or five atoms. The question which arises upon that statement is this: Are we to consider these multiples of sulphur, S^2, S^3, S^4, S^5, as being each a single negative radical, or are we to explain the composition of the polythionates in some manner that is more in accordance with the leading doctrines of the radical theory? Is it possible to show that these polythionates consist of simple sulphur salts formed by single radicals? My reply to those questions is, that the multiples of sulphur, S^2, S^3, S^4, S^5, act in no case as single negative radicals; that the above-framed synoptical formulæ give erroneous notions of the proximate constitution of the salts under consideration; and that it is possible to adduce facts to prove that sulphur acts like all other negative radicals, and produces salts with positive radicals, by combining therewith atom to atom. With these subjects for consideration before us, the reader will accompany me, with as much patience as possible, in the examination of a variety of instances and arguments upon which these theories turn.

The Pentathionates.

According to Wackenroder,[1] "five atoms of sulphurous acid and five atoms of hydrosulphuric acid, react upon one another in such a manner as to form one atom of pentathionic acid, five atoms of water, and five atoms of sulphur, which separate in the solid state: $5SO^2 + 5HS = S^5O^5 + 5HO + 5S$."

The acid thus produced can be concentrated over a water-bath till it obtains the spec. grav. of 1·3, and in vacuo the spec. grav. of 1·60, but it cannot be deprived of water, and its composition at the concentration of 1·5 is about one atom of S^5O^5 to nine atoms of H^2O.

Upon the radical theory, I account for this reaction as follows:

$$SO + HS = HSO + S.$$

This simple view of the reaction accounts for all the facts, and is, I think, the true one. The compound HSO is the simplest form of the series of oxidised sulphur salts, and it bears to the sulphates the same relation that aldehyde bears to the acetates. In short, to borrow a phrase from organic chemistry, it is the ALDIDE of the sulphur series, and this relation holds true even to the double salts of the two radicals that are produced by the combination of the aldehydes with the hydrated acids, or by the corresponding salts with metallic radicals:—

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[1] Gmelin's Handbook of Chemistry, II. 163.

	Acetic Series.	Sulphuric Series.
Aldehyde	M,C^2H^3O	M,SO
Acid	$M,C^2H^3O^2$	M,SO^2
Aldehydate	$M^2,(C^2H^3)^2O^3$	
Sulphite		M^2,S^2O^3.

Another method of producing a pentathionate is by the action of aqueous solution of sulphurous acid on dichloride (subchloride) of sulphur ClS^2. Thus:—

$$\left.\begin{matrix} ClS^2 + SO + \\ HHO,HHO \end{matrix}\right\} = \left\{\begin{matrix} HCl \\ 3HSO \end{matrix}\right.$$

A pentathionate can also be produced by the action of chloride of sulphur ClS upon water, the presence of sulphurous acid not being essential:—

$$ClS + HHO = HCl + HSO.$$

According to Kessler,[1] Persoz obtained pentathionic acid by decomposing hyposulphite of lead with hydrosulphuric acid.

EXPLANATION:—

Supposing the hyposulphite to be hydrated.	Supposing the hyposulphite to be anhydrous.
$\left.\begin{matrix} PbHS^2O^2 \\ + HS \end{matrix}\right\} = \left\{\begin{matrix} PbS \\ 2HSO \end{matrix}\right.$	$\left.\begin{matrix} Pb^2S^4O^3 \\ H^2S^2 \\ HHO \end{matrix}\right\} = \left\{\begin{matrix} 2PbS \\ 4HSO \\ \end{matrix}\right.$

The hydrated pentathionic acid produced by these different reactions is sufficiently explained by the formula HSO, which, in the nomenclature proposed in this work, would be called HYDRA SULPHATE. This compound, you will observe, can actually be obtained in the state of a concentrated solution, of the specific gravity of 1·6. But chemists, in their wonderful love for what is occult, rarely scruple to sacrifice the known and the simple, to favour the unknown and the complex. They ignore this hydrated acid, which has been procured experimentally, which anybody can make, and which has this simple formula, and they insist upon recognising an imaginary anhydrous pentathionic acid, which is said to agree with the formula S^5O^5, but which they have never seen, which nobody can make, and of which they probably will never have the least knowledge.

The pentathionic acid, or, as I may perhaps be allowed the liberty of calling it, HYDRA SULPHATE, is a very unstable compound, and to this circumstance must be attributed the fact of its not having forced chemists to give greater attention to it. A substance that comes frequently before us might be supposed to be able to command our notice; but when it has the property of disappearing as soon as its presence is announced, it goes not only out of sight but out of mind. Thus it is with hydra sulphate, the decomposition of which follows so closely upon its formation, that we have no time to make a satisfactory acquaintance with it.

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[1] Liebig and Kopp's Annual Report (1847-8), I. 287.

In consequence of the instability of this acid, it is impossible to convert HSO into MSO. When we attempt to do so, by adding, for example, KHO to HSO, instead of producing, by double decomposition, the products KSO and HHO, we decompose HSO, drive off more or less of its sulphur, and give rise to the so-called tetrathionates, trithionates, and other varieties of sulphur salts which we have presently to examine. But the acid which is so unstable when alone becomes stable when brought into combination, and we are consequently enabled to procure, by indirect means, a variety of salts in which MSO and HSO occur, not only in combination with one another, but with other sulphur salts in great variety and in greatly-varying proportions.

The Anhydrous Acid S,SO *corresponding to the Hydrated Acid* H,SO.

I have, at page 119, explained the relation that exists between the hydrated and the anhydrous sulphuric acids. I have shown that these are both to be considered as normal salts, and that the latter is produced by the decomposition of two atoms of the former:—

$$HSO^2 + HSO^2 = HHO + S,SO^2.$$

Precisely the same relationship exists between the acid HSO and the anhydride S,SO; for

$$HSO + HSO = HHO + S,SO.$$

This compound, which I may call SULPHA SULPHATE, is of great importance for the elucidation of the salts of the polythionic acids, but it is unknown in the free state, and we can only infer its existence from the composition and the properties of the salts of which it is a component. But supposing that we could isolate it, we should have a salt on the model of water, in which S would be an unoxidised positive radical, and SO an oxidised negative radical, together = S,SO.

The Hyposulphites.

The formula commonly given to the hyposulphites is KO,S^2O^2, where O = 8. If we double this formula to raise O to 16, and at the same time transpose the oxygen, we have the formula $K^2S^4O^3$. But this formula does not describe the greater part of the hyposulphites. Most of them contain H^2O in addition to what is expressed in the above formula; and Rose and other chemists have expressed a doubt whether it is possible for hyposulphites, free from water, to exist. It is, however, a question whether the hydrogen which is found in these salts exists there in the state of water. The quantity of it is always peculiar. It rarely agrees with the quantity of water of crystallisation which is commonly found with salts of different bases, but bears a specific relation to the quantity of sulphur which is present in each hyposulphite.

If we add together the above two formulæ ($K^2S^4O^3$ and HHO), we have $K^2H^2S^4O^4$, or, reduced to its simplest form, KHS^2O^2. This compound seems to be equivalent to an acid salt agreeing with the formula KSO + HSO, namely, a double or acid salt of the pentathionic acid. But if the hyposulphites were thus constituted, we might reasonably expect to find neutral salts of the formula KSO. Yet these salts only occur in cases where the basic radical is a metalloid or a negative hydrocarbon; such as

Chlorosulphuric acid = ClSO = Chlora sulphate.
Sulphobenzide = C^6H^5,SO = Phenyla sulphate.
Sulphonaphthaline = $C^{10}H^7$,SO = Naphtyla sulphate.
Sulphide of benzoyle = C^7H^5,SO = Benzyla sulphate.
Sulphide of acetyl = C^4H^3,SO = Acetyla sulphate.

We find no metallic salts of this formula, but we find an abundance both of organic and inorganic salts of the formula KHS^2O^2, not only simple but double, and even of more complex varieties. There are also plenty of anhydrous hyposulphites of the form $K^2S^4O^3$, and many compounds which appear to be constituted of these two forms of the salt, combined with one another in various proportions.

It is commonly said, that no such compound is known as hyposulphurous acid, either anhydrous or hydrated; but here, I think, we can derive some benefit from our investigation of the so-called pentathionic acid. Let us gather the facts together:—

HSO is certainly the composition of the hydrated pentathionic acid.
SSO is probably its corresponding anhydride.
MSO is the neutral salt which corresponds to the acid HSO, and which has been procured in salts where M is a negative radical, but not where M is a positive radical.
Then, KSO + HSO = KH,S^2O^2 is the double salt, or acid salt, of the series; and this is the composition of the *hydrated* hyposulphites, which can be procured in great variety.

If we join together two atoms of hydrated hyposulphite, and deprive the compound of one atom of water, we produce the *anhydrous* hyposulphite, which also occurs plentifully:

$$\left.\begin{matrix}KSO + HSO\\ KSO + HSO\end{matrix}\right\} - \left\{\begin{matrix}H\,O\\ H\end{matrix}\right\} = \left\{\begin{matrix}KSO + S\\ KSO + SO\end{matrix}\right\} = K^2S^4O^3.$$

According to these relations, the well-known but misunderstood hydrated pentathionic acid = HSO is, in fact, the "undiscovered" hydrated hyposulphurous acid; the compound SSO is the non-isolated anhydrous hyposulphurous acid; and the hydrated hyposulphite KSO + HSO is a double or acid pentathionate. These are sad complications in terms, and I will, therefore, simplify the matter by throwing aside the pentathionic theory, and stating the facts in other words, thus:—

HSO = HYDRA SULPHATE is the fundamental acid, or rather hydrogen salt, of the series of oxy-salts of sulphur. SSO is its anhydride.

KSO would be the normal salt of the series, but we cannot get it except with negative radicals, C^6H^5,SO, &c.

KSO + HSO = $KH(SO)^2$. POTASSA HYDRA BISULPHATE is the double salt or acid salt of the series, and this can be procured in great variety, constituting the salts now considered to be *hyposulphites combined with water*, according to the formula

$$K^2S^4O^3 + H^2O = \left\{\begin{matrix}KSO,HSO.\\ KSO,HSO.\end{matrix}\right.$$

The anhydrous salt $K^2S^4O^3 = \left\{\begin{matrix}KSO\\ KSO\\ S\,SO\end{matrix}\right\}$ is a triple salt, which bears to the salt KSO + HSO the same relation that the anhydrous bisulphate of potash = $\left\{\begin{matrix}KSO^2\\ KSO^2\\ SSO^3\end{matrix}\right\}$ bears to two atoms of the hydrated bisulphate of potash = $2(KSO^2 + HSO^2)$, according to the theory that I have explained at page 119. The relation is also the same as that which bichromate of potash bears to neutral chromate of potash, as is explained in the article on the "Chromates," page 126.

THE PENTATHIONATE OF BARYTA.—The only salt of the pentathionic acid which has been analysed is that of baryta. According to Lenoir,[1] this salt, obtained in crystals by precipitation with alcohol, contains

$$BaO,S^5O^5 + 2HO \quad \text{equal to} \quad Ba,S^5O^3 + HHO.$$
$$(\text{where } O = 8.) \qquad\qquad (\text{where } O = 16.)$$

The relation of the pentathionate of barytes to the hydrated pentathionic acid is shown in the following diagram:—

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[1] Liebig and Kopp's Annual Report (1847–8), I. 285.

HSO	BaSO	BaSO	BaSO
HSO	HSO	HSO	SSO
HSO	HSO	HSO	SSO
HSO	HSO	SSO	
HSO	HSO		
5 atoms of the Hydrated Acid commonly called 1 Acid + 2 Water.	1 atom of the Baryta-salt as it exists in solution.	1 atom of the Baryta-salt in crystals.	1 atom of the theoretical Anhydrous-salt.

The connection of the hyposulphites with the pentathionates is remarkably illustrated by the following comparisons :—

BaSO	BaSO	BaSO	BaSO
HSO	HSO	SSO	BaSO
HSO		SSO	SSO
SSO			
Crystallised Pentathionate of Barytes.	Crystallised Hyposulphite of Barytes.	Theoretical Anhydrous Pentathionate of Barytes.	Anhydrous Hyposulphite of Barytes.

I conclude from these examples, that the hyposulphites and pentathionates are both composed by the intercombination of simple salts of the formulæ HSO, MSO, SSO, and that no such thing exists as a pentathionic acid of the form HO,S^5O^5, and that there are no pentathionates, but such as are, like the hyposulphites, compounds of MSO with HSO and SSO.

The following processes illustrate the formation of the hyposulphites:—

1. When zinc is dissolved in an aqueous solution of sulphurous acid, we obtain, without liberation of hydrogen gas, a mixture of sulphite of zinc and hyposulphite of zinc.

a. Supposing Water not to Act.

$$Zn^4 + (SO)^6 = \left\{\begin{array}{l} Zn^2,S^2O^3 = \text{Neutral sulphite.} \\ Zn^2,S^4O^3 = \text{Anhydrous hyposulphite.} \end{array}\right.$$

b. Supposing Water to Act.

$$\left.\begin{array}{l} Zn^2 \\ (SO)^4 + HHO \end{array}\right\} = \left\{\begin{array}{l} ZnH,S^2O^3 = \text{Bisulphite.} \\ ZnH,S^2O^2 = \text{Hydrous hyposulphite.} \end{array}\right.$$

2. A hyposulphite is also produced when an aqueous solution of an alkaline sulphite is heated in a close vessel with an excess of sulphur.

a. Supposing Water not to Act.

$$\left.\begin{array}{c} Na^2,S^2O^3 \\ S^2 \end{array}\right\} = Na^2,S^4O^3 = \text{Anhydrous hyposulphite.}$$

b. Supposing Water to Act.

$$\left.\begin{array}{r} Na^2,S^2O^2 \\ S^2 \\ HHO \end{array}\right\} = \left\{\begin{array}{l} NaH,S^2O^2 \\ NaH,S^2O^2 \end{array}\right\} \text{Hydrous hyposulphite, 2 } \textit{atoms.}$$

In the presence of water, the hyposulphites are probably always formed in agreement with the formula MSO,HSO. Many of them crystallise in that state. This is the case with the hyposulphite of soda, perhaps the most important salt of the series, in consequence of its employment in the art of photography. This salt crystallises from its solution with so much water as to agree with the formula

$$NaSO,HSO + 2H^2O.$$

The hyposulphite of barytes and many others also crystallise in the form MSO,HSO. When these salts are dried they *gradually* lose their water, and pass, by intermediate stages, into the form of the anhydrous hyposulphites agreeing with the formula $M^2S^4O^3$. As an example of these progressive changes I may refer to a crystallised salt of potash, which has the formula $KH,(SO)^2$ = KSO,HSO. When this salt has been dried in vacuo, its composition is K^3H,S^6O^5; and when it has been deprived of all its water, it is K^2,S^4O^3. These relations are shown in the following diagram:—

$$\begin{array}{c} \text{3 atoms original Salt.} \\ \left.\begin{array}{l} KSO + HSO \\ KSO + HSO \\ KSO + HSO \end{array}\right\} \end{array} = \begin{array}{c} \text{Partially dried.} \\ \left\{\begin{array}{l} KSO + HSO \\ KSO + \quad SO \\ KSO + \quad S \end{array}\right\} \end{array} + H,HO \left\{ \begin{array}{c} \text{Expelled from} \\ \text{3 atoms.} \end{array}\right.$$

$$\begin{array}{c} \text{2 atoms original Salt.} \\ \left.\begin{array}{l} KSO + HSO \\ KSO + HSO \end{array}\right\} \end{array} = \begin{array}{c} \text{Wholly dried.} \\ \left\{\begin{array}{l} KSO + \quad SO \\ KSO + \quad S \end{array}\right\} \end{array} + H,HO \left\{ \begin{array}{c} \text{Expelled from} \\ \text{2 atoms.} \end{array}\right.$$

These examples prove that the salts of this series have, like the silicates, an extraordinary power of combining with one another, and also of combining with additional atoms of what is commonly, but improperly, called the *anhydrous* ACID. In this case, and in all such cases, the compound S,SO appears to me to be a perfect *salt*, and to combine as such with the other salts.

Although unwilling to multiply details, I must quote a few examples of hyposulphites, because I feel that the reader will naturally desire to see the important positions which I have advanced established firmly by sufficient evidence. Most of the hyposulphites agree with the two formulæ that I have explained, MSO + HSO and $M^2S^4O^3$. I shall not refer again to salts agreeing with those ordinary formulæ, but select those of more complex constitution.

EXAMPLES OF COMPLEX HYPOSULPHITES.

	Ultimate Constituents.			Assumed proximate Constituents.		
				Hydrous Salts.		Anhydrous Salts.
1.	Am^3,H;	S^6O^5	=	AmH,S^2O^2	+	$Am^2S^4O^3$.
2.	Am^2,Pb,H^3;	S^6O^6	=	$2(AmH,S^2O^2)$. PbH,S^2O^2.		
3.	Na^4,Pb^2;	$S^{12}O^9$	=	. . .	=	$2(Na^2S^4O^3)$. $Pb^2S^4O^3$.
4.	K^4,Pb^2,H^4;	$S^{12}O^{11}$	=	$4(KH,S^2O^2)$	+	$Pb^2S^4O^3$.
5.	K,Cu,H^2;	S^4O^4	=	KH,S^2O^2. CuH,S^2O^2.		
6.	K^6,Cu^2,H^6;	$S^{16}O^{15}$	=	$6(KH,S^2O^2)$	+	$Cu^2S^4O^3$.
7.	Na^3,Cu,H^2;	S^8O^7	=	$2(NaH,S^2O^2)$	+	$NaCu,S^4O^3$.
8.	Na^2,Cu^3,H^5;	$S^{10}O^{10}$	=	$2(NaH,S^2O^2)$. $3(CuH,S^2O^2)$.		
9.	Cu^5,Hg^3;	$S^{16}O^{12}$	=	. . .		$2(Cu^2S^4O^3)$ $CuHg,S^4O^3$. $Hg^2S^4O^3$.
10.	Am^8,Hg^3,H^4;	$S^{20}O^{17}$	=	$4(AmH,S^2O^2)$	+	$2(Am^2S^4O^3)$. $Hg^2S^4O^3$.
11.	Na^2,Ag^2,H^2;	S^8O^7	=	$2(NaH,S^2O^2)$	+	$Ag^2S^4O^3$.
12.	Na^4,Ag^2,H^4;	$S^{12}O^{11}$	=	$4(NaH,S^2O^2)$	+	$Ag^2S^4O^3$.
13.	Na^4,Ag^2;	$S^{12}O^9$	=	. . .		$2(Na^2S^4O^3)$. $(Ag^2S^4O^3)$.
14.	Na^3,Au,H^4;	S^8O^8	=	$3(NaH,S^2O^2)$. AuH,S^2O^2.		

AUTHORITIES. (*The references are to* GMELIN'S *Handbook of Chemistry.*)

1. Rammelsberg, II. 454. Hyposulphite of ammonia = $3(NH^4O,S^2O^2) + HO$.
2. Rammelsberg, V. 159. Hyposulphite of lead-oxide and ammonia = $2(NH^4O,S^2O^2) + PbO,S^2O^2 + 3Aq$.
3. Lens, V. 162. Hyposulphite of lead-oxide and soda = $2(NaO,S^2O^2) + PbO,S^2O^2$.
4. Rammelsberg, V. 161. Hyposulphite of lead-oxide and potash = $2(KO,S^2O^2) + PbO,S^2O^2 + 2Aq$.
5. Rammelsberg, V. 459. Hyposulphite of cuprous-oxide and potash; with 1 atom of potash-salt = $KO,S^2O^2 + Cu^2O,S^2O^2 + 2Aq$.
6. Rammelsberg, V. 459. Hyposulphite of cuprous-oxide and potash; with 3 atoms of potash-salt = $3(KO,S^2O^2) + Cu^2O,S^2O^2 + 3Aq$.

7. Lenz, V. 492. Hyposulphite of cuprous-oxide and soda; with 1 atom of copper-salt to 3 atoms of soda-salt = $3(NaO,S^2O^2) + Cu^2O,S^2O^2 + 2Aq$.
8. Lenz, V. 462. Hyposulphite of cuprous-oxide and soda; with 3 atoms of copper-salt to 2 atoms of soda-salt = $2(NaO,S^2O^2) + 3(Cu^2O,S^2O^2) + 5Aq$.
9. Rammelsberg, VI. 131. Hyposulphite of mercurous and cuprous-oxide = $5(Cu^2O,S^2O^2) + 3(Hg^2O,S^2O^2)$.
10. Rammelsberg, VI. 78. Hyposulphite of mercuric-oxide and ammonia = $4(NH^4O,S^2O^2) + HgO,S^2O^2 + 2Aq$.
11. Lenz, VI. 180. Hyposulphite of silver-oxide and soda = $NaO,S^2O^2 + AgO,S^2O^2 + Aq$.
12. Lenz, VI. 180. Hyposulphite of silver-oxide and soda = $2(NaO,S^2O^2) + AgO,S^2O^2 + 2Aq$.
13. Sir John Herschel, VI. 179. Hyposulphite of silver-oxide and soda = $2(NaO,S^2O^2) + AgO,S^2O^2$.
14. Fordos and Gélis, VI. 231. Hyposulphite of aurous-oxide and soda = $3(NaO,S^2O^2) + AuO,S^2O^2 + 4Aq$.

Except among the silicates and the salts of the metallic acids, it would perhaps be difficult to find a series of salts of more complicated relations than the series exhibited in the preceding Table. The complication arises from the circumstance that the normal salt MSO, which is the basis of the series, though unstable when isolated, acquires stability when in combination, and, like all the oxy-salts of sulphur, has an unlimited tendency to form complex salts.

In considering the facts that are exhibited in this Table, we speedily come to the question,—What is the condition of the hydrogen in these salts? Does it act as *base* to the oxidised radical SO, or does it, as all the authorities that I have quoted assume, exist in the condition of *water?* I admit that the last view simplifies the formulæ materially; but the mere simplification of formulæ is not the sole object of our inquiry. What we want mainly to understand is the intimate nature of the composition of these salts; how it is—in what order—the elements of which they are composed are combined with one another. Looking at the whole series, at all the kinds of the salts of the polythionic acid, it seems to me that there is no probability that the hydrogen exists in the state of water, but that there is throughout a constant recurrence of the salts HSO, MSO, SSO, and that of these elementary salts the hyposulphites and pentathionates are made up. We perceive everywhere in this Table, that if we consider SO as an oxidised negative radical, there is for every atom of it a corresponding positive radical—sometimes H, sometimes M, sometimes S; all of them unoxidised. This is consequently a demonstration of the truth of the proposition, which I enunciated at page 158, that with certain specified exemptions, one positive radical never combines with a multiple number of oxidised sulphur atoms considered as one negative radical; but that every single oxidised sulphur atom acts as a negative radical, and combines with one positive radical.

But what, it may be asked, shall we gain by admitting the divisibility of these compounds into innumerable little normal salts? I will endeavour to answer this question. It is admitted, that plants feed on water = HHO, carbonic acid = CO^2, ammonia = NH^3, with minute quantities of S and other inorganic elements. We know also that animals feed on plants. But when we come, in the practice of physiological chemistry, to examine the component parts of animals, we find, of course, the elements upon which the plants feed, but we find them in the condition of substances that have the following composition:—

			Total atoms.
Albumen . .	$C^{216}H^{169}N^{27}S^2O^{68}$	=	482
Caseine . . .	$C^{288}H^{228}N^{36}S^2O^{90}$	=	644
Flesh fibrine .	$C^{216}H^{169}N^{27}S^2O^{68}$	=	482
Blood fibrine .	$C^{298}H^{228}N^{40}S^2O^{92}$	=	660

I copy these formulæ from Professor GREGORY's *Handbook of Organic Chemistry*, published in 1856. They represent therefore the present state of chemical knowledge as respects these compounds. We have here a statement of the *ultimate* constitution of a number of important compounds, but no statement of their *proximate* constitution. We cannot tell how these multitudes of atoms are combined with one another, or of what innumerable little normal salts the complex salts are composed. Between the food of plants—CO^2, HHO, NH^3, S—and blood fibrine $C^{298}H^{228}N^{40}S^2O^{92}$, there is an immense chasm. We desire to bridge it over. We want to know how the raw material has been worked up into this finished manufacture. We would fain follow the original elements, C, and H, and N, and S, through all their transmigrations and metamorphoses till they united to form the complex animal compound which so much perplexes and astonishes us.

Well, then, the proper course to pursue is certainly *not* that of massing the elements into vast clumps, and forbearing to inquire whether these clumps are not divisible into smaller, and smaller, and smaller groups. On the contrary, the duty of the chemist is to examine the works of Nature with the greatest minuteness, to watch, as far as his power permits, the working of every atom of the substances which he undertakes to examine, and not to satisfy himself with looking at them cursorily and in the gross. These are the reasons which have induced me to point out what I consider a defect in the manner in which chemists have examined the salts of sulphur. They have stopped too readily after having grouped the elements into clumps, and have not examined with proper care in what manner these clumps are constituted.

By persisting in such a course with salts in general, they will never arrive at the comprehension of the constitution of such compounds as albumen, caseine, and fibrine, and never properly appreciate the physiological chemistry either of animals or plants. This is why I propose that we should push our analytical inquiries into the constitution, not only of the oxy-salts of sulphur, but of all salts, to the extremest possible extent of minuteness.

The Tetrathionates.

The Tetrathionates are produced by the action of iodine on solutions of the hyposulphites. Thus:—

$$\left\{\begin{matrix} KSO + HSO \\ KSO + HSO \end{matrix}\right\} + I = KI + \left\{\begin{matrix} SO + HSO \\ KSO + HSO \end{matrix}\right\}$$

2 atoms Hyposulphite. 1 atom Tetrathionate.

Supposing the tetrathionate thus formed to be dried and deprived of one atom of water = HHO, it becomes $KSO,SO + SSO = KS^4O^3$.

The following tetrathionates are nearly all that have been analysed—

Analytical Formulæ.	Synoptical Formulæ.
$Ba SO,SO + 2HSO$	$= Ba H^2; S^4O^4 = Ba S^4O^3 + Aq.$
$PbSO,SO + 2HSO$	$= PbH^2; S^4O^4 = PbS^4O^3 + Aq.$
$Sr SO,SO + 2HSO + Aq^2$	$= Sr H^6; S^4O^6 = Sr S^4O^3 + Aq^3.$
$K SO,SO + SSO$	$= K ; S^4O^3 = K S^4O^3.$

The synoptical formula seem to show the presence of the poly-sulphur radical S^4, but the analytical formulæ account for the salts in another manner. They are, namely, compounds of the normal sulphates HSO, MSO, and SSO with SO, and there is apparently no such compound as the assumed tetrathionic acid HO,S^4O^5, the real acid being composed as follows: $H^rSO,SO + HSO + HSO = H^3S^4O^4$; where H^r is the only atom that is replaceable by a metal.

The Trithionates.

The trithionates are produced by digesting, for three or four days, a saturated solution of bisulphite of potash on flowers of sulphur. The products vary according to the duration of the digestion, the heat at which it is effected, and other circumstances. They are, generally, trithionate of potash, more or less of sulphate and of hyposulphite, a quantity of sulphurous acid which is evolved during the digestion, and a solution from which free sulphur is afterwards deposited. The variety and variableness of these products render it impossible to explain the operation in an equation; but the chief points can be satisfactorily accounted for.

1. The formula of bisulphite of potash, according to the radical theory, is $KSOO + HSO$. With S, this can produce $KSO + HSO$ = hyposulphite of potash + SO = sulphurous acid.

2. Two atoms of bisulphite of potash are equal to one atom each of trithionate of potash and sulphate of potash, thus:—

$$\left.\begin{array}{l} KSO^2 + HSO \\ KSO^2 + HSO \end{array}\right\} = \left\{\begin{array}{ll} KSO^2 + HSO + HSO & = \text{Trithionate.} \\ KSO^2 & = \text{Sulphate.} \end{array}\right.$$

3. If water is presumed to take part in the operation, and a little oxygen is taken up from the air during the prolonged digestion, the action may be represented thus:—

$$\left.\begin{array}{l} KSO^2 + HSO \\ KSO^2 + HSO \\ S^2 + HHO + O \end{array}\right\} = \left\{\begin{array}{l} KSO^2 + HSO + HSO. \\ KSO^2 + HSO + HSO. \\ \end{array}\right.$$

4. The trithionates can also be prepared by exposing a solution of hyposulphite of zinc to spontaneous decomposition:—

$$\left.\begin{array}{l} ZnSO,HSO \\ ZnSO,HSO \end{array}\right\} = ZnS + \left\{\begin{array}{l} ZnSOO. \\ (HSO)^2 \end{array}\right\}$$

The composition of crystallized trithionate of barytes has been found to be $BaH^2S^3O^4$, which is equal to $BaSO^2 + (HSO)^2$. The formulæ of the crystallized anhydrous trithionate of potash is $KSO^2 + SSO$, or KS^3O^3. Hence, the analytical formulæ of these salts are as follow:—

The anhydrous trithionates are =	The hydrous trithionates are =
M,SOO	M,SOO
$S,SO.$	H,SO
	$H,SO.$

Their synoptical formulæ are,

$$\text{Anhydrous trithionates} = M,S^3O^3$$
$$\text{Hydrous trithionates} \left\{\begin{array}{l} = MH^2,S^3O^4 \\ = M,S^3O^3 + H^2O. \end{array}\right.$$

When the trithionate of potash is made red hot, it is decomposed into one atom each of sulphur, sulphurous acid, and sulphate of potash.—*Langlois.*

$$KSO^2 + S,SO = KSO^2 + S + SO.$$

When a solution of trithionate of potash is boiled, it is resolved into sulphate of potash, sulphurous acid, and sulphur.—*Pelouze.*

$$KSO^2 + HSO + HSO = KSO^2 + SO + S + HHO.$$

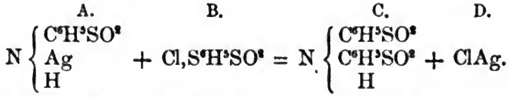
The synoptical formulæ seem to indicate the existence of the multiple radical S^2, but all other circumstances discredit that assumption.

The aqueous pentathionic acid, when acted on by an alkali, suffers decomposition, liberates water and one or two atoms of sulphur, and produces a tetrathionate or trithionate:—

$$KH^4,S^5O^5 \text{ less } S \text{ and } H^2O = KH^2,S^4O^4 = \text{Tetrathionate.}$$
$$KH^4,S^5O^5 \text{ less } S^2 \text{ and } H^2O = KH^2,S^3O^4 = \text{Trithionate.}$$

The Sulphenetes.

In the proposed nomenclature a SULPHENETE would be a salt containing two atoms of sulphur and two atoms of oxygen = S^2O^2. No such salts are at present recognised, but I have no doubt that we shall find them hereafter. In tracing the constitution of the tetrathionates, I have shown that they may be considered to consist of a *biacid* salt, of the form MSO,SO in combination with S,SO or with HSO,HSO. This biacid salt MSO,SO, if isolated, would be a sulphenete. Thus, KSO,SO = KS^2O^2 = Potassa sulphenete. Now, though I cannot point out any *single* salts of this composition, I can refer to a *double* salt, which will explain my view of its composition. I copy the following equation from Gerhardt's discussion of the "type ammonia."[1] In this equation S signifies what I call S^2. The other symbols agree with mine.



$$\overset{\text{A.}}{N\left\{\begin{array}{l}C^6H^5SO^2\\Ag\\H\end{array}\right.} + \overset{\text{B.}}{Cl,S^6H^5SO^2} = \overset{\text{C.}}{N\left\{\begin{array}{c}C^6H^5SO^2\\C^6H^5SO^2\\H\end{array}\right.} + \overset{\text{D.}}{ClAg.}$$

Azoture of Sulpho-phenyle of Silver and of Hydrogen.

Chloride of Sulpho-phenyle.

Azoture of Disulpho-phenyle and Hydrogen.

It is absurd to consider oxidised double salts like these as "ammonias," and I shall arrange the symbols in a different manner:—

A is a salt of the class that I have pointed out as double sulphates (using that word in its new sense), in which one of the basic radicals is silver and the other an amidogen containing one atom of phenyl = Ag; SO + ZH,C^6H^5; SO.

B is a similar double sulphate, in which the basic radicals are chlorine and phenyl = Cl; SO + C^6H^5; SO.

---

[1] Traité de Chimie Organique, tom. iv. 770.

When these two salts act upon one another, chloride of silver (D) is produced, and the other elements all rest in combination to form the salt C.

$$\begin{array}{l} \qquad\qquad A + B. \qquad\qquad\qquad\qquad\qquad D. \qquad\qquad\qquad\qquad C. \\ \left.\begin{array}{l} A = AgSO + ZH,C^6H^5; SO \\ B = Cl\,SO + \qquad C^6H^5; SO \end{array}\right\} = \left\{\begin{array}{l} Ag \\ Cl \end{array}\right\} + \left\{\begin{array}{l} SO + ZH,C^6H^5; SO \\ SO + \qquad C^6H^5; SO. \end{array}\right. \end{array}$$

This last salt (C) is consequently the double sulphenete, $ZH,C^6H^5; S^2O^2 + C^6H^5; S^2O^2$. The normal sulphenete will no doubt soon be found, if it is searched for.

The Sulphites.

The composition of the sulphites, according to the radical theory, and on the assumption that the atomic weight of sulphur is 16, is represented by the following formulæ:—

Analytical Formula.	Synoptical Formula.
$MO,SO + M,SO$	$M,M;\ S^2O^2$

These formulæ, however, represent the Neutral Sulphites. The Acid Sulphites, or Bisulphites, are constituted as follows:—

Analytical Formula.	Synoptical Formula.
$MO,SO + H,SO$	$M,H;\ S^2O^2.$

There is no hydrated acid corresponding to these sulphites. According to the synoptical formula, a sulphite is a bibasic salt. According to the analytical formula, it is a double salt consisting of a sulphate MSO^2, in combination with a salt on the model of water containing only one atom of oxygen = MSO. Hence the hydrated acid would be a compound of hydrated sulphuric acid with hydrated pentathionic acid—

$$HO,SO + HSO = H,H;\ S^2O^2.$$

NOMENCLATURE OF THE TWO KINDS OF SULPHITE.

Neutral sulphite: $K,K; S^2O^2$ POTASSEN SULPHENITE.
Acid sulphite: $K,H; S^2O^2$ POTASSA HYDRA SULPHENITE.

The sulphites are prepared by passing sulphurous acid gas = SO into solutions of caustic alkalies or carbonates of alkalies. The reactions that take place are shown by the following equations:—

$$a.\ KHO + SO + SO = K,H;\ S^2O^2$$

$$b.\ \left.\begin{array}{l} KHO + SO \\ KHO + SO \end{array}\right\} = \left\{\begin{array}{l} K.K;\ S^2O^2 \\ \quad H,HO. \end{array}\right.$$

$$c.\ \left.\begin{array}{l} K,K;\ CO^2 \\ SO + SO \end{array}\right\} = \left\{\begin{array}{l} K,K;\ S^2O^2 \\ \qquad C\,O^2. \end{array}\right.$$

According to *a*), one atom of caustic potash and two atoms of sulphurous acid produce one atom of bisulphite of potash. According to *b*), two atoms of caustic potash and two atoms of sulphurous acid produce one atom of water and one atom of neutral sulphite of potash. According to *c*), one atom of carbonate of potash and two atoms of sulphurous acid produce one atom of neutral sulphite of potash and one atom of carbonic acid.

The sulphites of the alkaline earths (Ba, Sr, Ca) which are insoluble in water, dissolve in an aqueous solution of sulphurous acid. The reason of this is, that the insoluble neutral sulphites become converted into soluble bisulphites:—

$$\left.\begin{matrix}\text{Ba,Ba; S}^2\text{O}^3 + \\ \text{SO} + \text{SO} + \text{HHO}\end{matrix}\right\} = \left\{\begin{matrix}\text{Ba,H; S}^2\text{O}^3 \\ \text{Ba,H; S}^2\text{O}^3.\end{matrix}\right.$$

Many neutral sulphites are decomposed by ignition into ¾ sulphate and ¼ sulphide:—

$$\left.\begin{matrix}\text{Pb,Pb; S}^2\text{O}^3 \\ \text{Pb,Pb; S}^2\text{O}^3\end{matrix}\right\} = \left\{\begin{matrix}3(\text{PbSO}^4) \\ \text{PbS.}\end{matrix}\right.$$

When sulphites are treated with hydrochloric acid, sulphurous acid gas is liberated, and no sulphates are formed:—

$$\left.\begin{matrix}\text{Ag,Ag, S}^2\text{O}^3 \\ \text{H,H,Cl}^2\end{matrix}\right\} = \left\{\begin{matrix}\text{AgCl,AgCl} \\ \text{SO,SO} + \text{HHO.}\end{matrix}\right.$$

When sulphites are treated with nitric acid in the cold, sulphurous acid gas is liberated:—

$$\left.\begin{matrix}\text{K,K; S}^2\text{O}^3 \\ \text{H,NO}^3 \\ \text{H,NO}^3\end{matrix}\right\} = \left\{\begin{matrix}\text{K,NO}^3 \\ \text{K,NO}^3 \\ \text{SO,SO} + \text{HHO.}\end{matrix}\right.$$

When a mixture of sulphites and nitric acid is boiled, peroxide of nitrogen is expelled and sulphates are formed:—

$$\left.\begin{matrix}\text{K,K; S}^2\text{O}^3 \\ \text{HO,NO}^2 \\ \text{HO,NO}^2\end{matrix}\right\} = \left\{\begin{matrix}\text{KSO}^2 \\ \text{KSO}^2 \\ \text{NO}^2\text{,NO}^2\text{,} + \text{HHO.}\end{matrix}\right.$$

The Hyposulphates.

The hyposulphates are constituted as follows:—

Analytical Formula.	Synoptical Formula.
KO,SO; SO	$\text{K,S}^2\text{O}^3$

The hyposulphate of manganese is produced by passing sulphurous acid gas into water containing peroxide of manganese in suspension:

$$MnO + SO,SO = MnO,SO + SO = MnS^2O^3.$$

When heated, the hyposulphates give off one atom of sulphurous acid and leave a sulphate of the base:

$$MnS^2O^3 = MnSO^2 + SO.$$

A boiling solution of a hyposulphate, when acted on by chlorine or nitric acid, produces two atoms of sulphuric acid for each atom of base. Thus:—

With Nitric Acid.

$$\left.\begin{array}{r}\left.\begin{array}{r}KO,SO\\ SO\end{array}\right\}\\ HO,NOO\end{array}\right\} = \left\{\begin{array}{l}KO,SO.\\ HO,SO.\\ \quad NOO.\end{array}\right.$$

With Chlorine.

$$\left.\begin{array}{r}\left.\begin{array}{r}KO,SO\\ SO\end{array}\right\}\\ H,HO \quad\\ Cl\end{array}\right\} = \left\{\begin{array}{l}KO,SO.\\ HO,SO.\\ \\ \quad H,Cl.\end{array}\right.$$

Hyposulphuric acid can be procured in the state of hydrate $= HS^2O^3$ HYDRA SULPHENITE.

Peculiarities in the Saturating Capacities of the Oxy-Sulphur Acids.

1]. On comparing together the synoptical formulæ of the sulphites and hyposulphates, we observe a very remarkable coincidence:—

$$K,K;\ S^2O^3 = \text{Sulphite.}$$
$$K,\ S^2O^3 = \text{Hyposulphate.}$$

Here are two classes of salts, both having acid radicals of the same nature and quantity, and both with the same number of atoms of oxygen, yet differing essentially in the important circumstance, that the salts of the one class are monobasic, and those of the other class, bibasic. The synoptical formulæ show nothing to explain this peculiarity, but the analytical formulæ clear up all mystery:—

$$KO,SO + KSO = \text{Sulphite.}$$
$$KO,SO + \quad SO = \text{Hyposulphate.}$$

Namely, the sulphite is both bibasic and biacid. The hyposulphate is biacid but not bibasic.

This explanation of the rational composition of the sulphites and hyposulphates is totally lost, if, following MM. Gerhardt and Williamson, we fix the atomic weight of sulphur at 32; for then we have the formulæ $KKSO^3$ and KSO^3; one representing a bibasic, and the other a monobasic salt, with no clue to the significance of so remarkable a peculiarity.

The proportions of sulphur and oxygen which are present in the sulphites and hyposulphates, are the same as the proportions which constitute the compound called anhydrous sulphuric acid :—

Anhydrous Sulphuric Acid.	Neutral Sulphite of Potash.	Hyposulphate of Potash.
SO	K,SO	SO
SOO	K,SOO	K,SOO

These relations explain many phenomena that occur when sulphuric acid acts upon organic radicals.

2]. A similar anomaly, as to saturating power, appears when we compare together the anhydrous tetrathionates and the anhydrous hyposulphites, expressed in synoptical formulæ :—

K,S^4O^3 = Tetrathionate.
KK,S^4O^3 = Hyposulphite.

The cause of this difference is shown in the analytical formulæ :—

$KSO + SO + SSO$ = The Anhydrous tetrathionate.
$KSO + KSO + SSO$ = The Anhydrous hyposulphite.

3]. The following salts exhibit a third pair of examples of this peculiarity :—

$M ; S^2O^2$ = Sulphenete (Hypothetical). See page 170.
$MH ; S^2O^2$ = Hydrous hyposulphite.

The analytical formulæ of which salts are :—

$MSO + SO$ = Sulphenete.
$MSO + HSO$ = Hydrous hyposulphite.

4]. I might even notice a fourth pair of such salts :—

$ZH,C^6H^5 ; C^6H^5 ; S^4O^4$ = Double sulphenete. See page 170.
$K,H,H ; S^4O^4$ = Hydrous tetrathionate.

The analytical formulæ of this pair of salts are :—

$$\left\{\begin{array}{r} ZH,C^6H^5 ; SO + SO \\ C^6H^5 ; SO + SO \end{array}\right\} \text{Double sulphenete.}$$

$$\left\{\begin{array}{r} KSO,SO + H,SO \\ H,SO \end{array}\right\} \text{Hydrous tetrathionate.}$$

Facts of this sort should not be forgotten when you inquire, What is the nature of the bibasic and biacid power?

How are you to know a sulphite from a hyposulphate? Both contain

S^2O^3, but the sulphite contains two positive radicals, the hyposulphate only one positive radical. The distinction seems to be almost self-evident; yet the terms sulphite and hyposulphate are applied frequently, in books on organic chemistry, to compounds for which they are totally unfit. Such cases occur even in Gmelin's Handbook. In discriminating the oxy-sulphur salts, attention must always be paid to *three* particulars, namely, the number of atoms of sulphur, of oxygen, and of the positive radicals. The relation, not of any two of these, but of the whole, to one another, determines the nature of the salt; for we have seen, that the acids S^3O^3, S^4O^3, and S^2O^3, can saturate either M or MM; and that MM can saturate either S^4O^3, S^3O^3, or S^2O^3, or *twice that quantity of any one of them.* I repeat, therefore, that the relations of these three components of the salts must be carefully determined in each case, and that the various oxy-sulphur salts are to be formulated and named according to such threefold determinations. Hence, the formula MS^2O^3 will signify a hyposulphate, and the formula MM,S^2O^3 will signify a sulphite; so also, MSO^2 will signify a sulphate, and $MSO^2 + HSO^2$ will signify a bisulphate; *whatever may be the nature of the radical which is denoted by M*, provided always that it IS a radical, and is known to act as a radical in other cases.

Nomenclature of the Complex Oxy-Sulphur Salts.

An atom of sulphur weighing 16 combines with an atom of oxygen of the same weight to produce an atom of sulphurous acid = SO. This is the prime radical of all the oxysalts of sulphur.

SO combine with H, to produce the salt H,SO. This can be obtained in aqueous solution of the specific gravity of 1·6, but it cannot be isolated. It has been called pentathionic acid. I call it *hydra sulphate.* It can produce salts of the form MSO, where M is a negative radical, but not where M is a positive radical. It can however produce acid salts of the form MSO + HSO, where M is a positive radical. These salts are now called hyposulphites. I propose to call them *bisulphates.* Thus $K,H;(SO)^2$ is *potassa hydra bisulphate.* Hydra sulphate produces an anhydride of the form S,SO = *sulpha sulphate.* This combines with salts of the form MSO to produce anhydrous hyposulphites of the form PbSO, PbSO, SSO = $Pb^2S^4O^3$, which may be called *plumben sulphonite.* These simpler varieties of hyposulphites combine with one another to produce a series of extremely complex salts of which I have given some examples at page 165. I do not propose to apply systematic names to these complex salts, because it is certain that they would never be used. The names in present use, as given at page 165, are vague and inaccurate; one single term "hyposulphite" being applied to salts of extremely different constitution. Such error-teaching names are worse than useless. It is better to depend upon the formulæ for information. The new nomenclature could express every one of these salts with precision, but only in words of complexity corresponding to the complexity of the salts upon whose formulæ they would be framed.

I will, however, give a few examples of the names of these salts, specifying the proximate constituents as they appear in the text at page 165:—

1. $AmH,S^2O^2 + Am^2S^4O^3$. *Ammona hydra bisulphate cum ammonen sulphonite.*
2. $2(AmH,S^2O^2) + PbH,S^2O^2$. *Bis ammona hydra bisulphate cum plumba hydra bisulphate.*
3. $2(Na^2S^4O^3) + Pb^2S^4O^3$. *Bis natren sulphonite cum plumben sulphonite.*
4. $4(KH,S^2O^2) + Pb^2S^4O^3$. *Tetrakis plumba hydra bisulphate cum plumben sulphonite.*

The critic who feels disposed to censure the length of these names will be pleased to bear in mind that they are not merely hard meaningless words, but that they contain an account of the composition of the respective salts, and so render it needless to state that composition in the description of the salts.

The pentathionates are compound salts of the kind that I propose to call *sulphates*, such as BaSO,HSO,HSO,SSO, or BaSO,SSO,SSO. See page 163. The names expressive of these two formulæ are—

$BaSO,(HSO)^2,SSO$. *Baryta sulphate bis hydra sulphate cum sulpha sulphate.*

$BaSO,(SSO)^2$. *Baryta sulphate, bis sulpha sulphate.*

But if the formulæ of these salts are thrown into the closest synoptical form, (which, however, hides the proximate constitution,) they become—

BaH^2,S^5O^4. *Baryta hydren sulphunote.*
Ba,S^5O^3. *Baryta sulphunite.*

The tetrathionates are BaSO,SO + HSO,HSO. The first division of this formula consists of BaSO combined with SO, just in the same manner as the hyposulphates (page 172) consist of $BaSO^2$ combined with SO. The other part of the formula consists of two atoms of the hydrated acid HSO. These two atoms of acid seem to be liable to produce an anhydride, and so form the salt KSO,SO + SSO.

$BaS^2O^2,(HSO)^2$. *Baryta bisulphate bis hydra sulphate.*
BaS^2O^2,SSO. *Baryta bisulphate cum sulpha sulphate.*

Expressed synoptically, these two salts will be—

$BaH^2,(SO)^4$ = *Baryta hydren tetrasulphate.*
Ba,S^4O^3 = *Baryta sulphonite.*

The trithionates are $ZnSO^2 + (HSO)^2$ or $ZnSO^2 + SSO$. The first part of this formula signifies the compound which is called at present a sulphate, but which the new nomenclature changes to *sulphete.* The other part of the formulæ is similar to that of the tetrathionates. The proposed nomenclature of the trithionates is as follows:—

$ZnH^2S^3O^4$ = *Zinca hydren sulphinote.*
ZnS^3O^3 = *Zinca sulphinite.*

The above classes of sulphur salts are, at present, of very little importance in comparison with the following:

a). The salts which are now called SULPHATES, but which I propose to term SULPHETES.

b). The salts now called SULPHITES. These are compounds of MSO with MSO^2, that is to say, of the two salts that, in the new nomenclature, are called *sulphates* and *sulphetes.* The double salt assumes the character of a bibasic salt K,K; S^2O^3 = POTASSEN SULPHENITE.

c). The salts that are at present called HYPOSULPHATES. These salts are composed of the salts now called sulphates, in combination with sulphurous acid. Thus $KSO^2 + SO = K,S^2O^3$ = POTASSA SULPHENITE.

The Oxalates.

According to Professor Miller, the formula of hydrated oxalic acid is HO, C^2O^3, and that of the oxalate of silver is AgO,C^2O^3. If I double the atomic weight of the carbon and oxygen, these formulæ become:—

H, CO^2 = HYDRA CARBETE.
Ag,CO^2 = ARGENTA CARBETE.

Professor Miller gives the following account of the different classes of oxalates: "With the alkalies, oxalic acid forms three classes of salts, one of which contains one equivalent of base to one equivalent of acid, of which the oxalate of ammonia (H^4NO,C^2O^3+aq) is an example. The second class contains two equivalents of acid to one of a fixed base. Binoxalate of potash, or the salt of sorrel ($KO,HO, 2C^2O^3$+2aq) is an instance of this description; whilst the third class, which is exemplified by quadroxalate of potash ($KO,3HO,4C^2O^3$+4 aq), contains the unusual proportion of four equivalents of acid to one of a fixed base. It is very probable that oxalic acid belongs to the class of acids termed bibasic."—ELEMENTS OF CHEMISTRY, ii., p. 645.

On the Radical Theory, these salts may be represented thus:—

$ZH^4, \quad CO^2 + \tfrac{1}{2}$ aq = Ammona carbete demi-aquate.
$K,H; (CO^2)^2 +$ aq = Potassa hydra bicarbete aquate.
$K,H^3; (CO^2)^4 + 2$ aq = Potassa hydrine tetracarbete aquete.

Gerhardt's account of the oxalates is as follows:—

"Oxalic acid is a most energetic bibasic acid.

"The composition of the *neutral oxalates* is represented, in a general manner, by

$$C^4M^2O^8 = C^4O^6 \begin{cases} MO \\ MO \end{cases} = 2(C^2O^3,MO).$$

"The *binoxalates*, or *acid oxalates*, contain—

$$C^4HMO^8 = C^4O^6 \begin{cases} MO \\ HO \end{cases} = (C^2O^3,HO + C^2O^3,MO).$$

"There also exist *quadroxalates;* that is to say, combinations of oxalic acid with binoxalates:—

$$\left.\begin{matrix} C^4HMO^8 \\ C^4H^2\ O^8 \end{matrix}\right\} = \left\{\begin{matrix} C^4O^6 \begin{cases} MO \\ HO \end{cases} \\ \\ C^4O^6 \begin{cases} HO \\ HO \end{cases} \end{matrix}\right\} = (3C^2O^3,HO + C^2O^3,MO)."$$

—*Traité de Chimie Organique*, tom. I. 243.

According to the radical theory, these salts are formulated as follows:—

Neutral Oxalates.	**Acid Oxalates.**	**Quadroxalates.**
MCO^2	$MCO^2 + HCO^2$, or $MH\ (CO^2)^2$	$MCO^2 + 3(HCO^2)$, or $MH^3(CO^2)^4$.

The question whether oxalic acid is MONOBASIC or BIBASIC, is analogous to the similar inquiry respecting sulphuric acid. The arguments that have been maintained for and against the bibasicity of the latter bear equally upon the bibasicity of the former. If the arguments of MM. Gerhardt and Williamson, which I have quoted between pages 144 and 156, prove to the reader that sulphuric acid is bibasic, then he may assume at once that oxalic acid also is bibasic. If the arguments which I have urged in reply to those chemists prove that sulphuric acid is monobasic, they serve equally well to prove that oxalic acid is monobasic. I consider the question, therefore, as sufficiently examined, and I assume the decision upon it to be that oxalic acid is MONOBASIC.

Examples of Oxalates.

a. Oxalates with one basic radical:—

H, CO^2
Am, CO^2
K, CO^2
Na, CO^2
Ca, CO^2

Ag, CO^2
Pb, CO^2
Zn, CO^2
Cuc, CO^2
Alc, CO^2

Fe, CO^2
Fec, CO^2
Hg, CO^2
Hgc, CO^2
Crc, CO^2

Co, CO^2
Ni, CO^2
U, CO^2
$C H^3, CO^2$
C^4H^5, CO^2

b. Oxalates with two basic radicals:—

$AmCrc; C^2O^4$
$AmMn; C^2O^4$
$KCuc; C^2O^4$
$KZn; C^2O^4$
$KCrc; C^2O^4$

$KSbc; C^2O^4$
$KFec; C^2O^4$
$NaAlc; C^2O^4$
$NaFec; C^2O^4$
$NaCrc; C^2O^4$

$BaAlc; C^2O^4$
$BaFec; C^2O^4$
$CaCrc; C^2O^4$
$AgCrc; C^2O^4$
$PbCrc; C^2O^4$

c. Oxalates with three basic radicals:—

$Am^2,Zn; (CO^2)^3$ $CaCrc^2; (CO^2)^3$

d. Oxalates with four basic radicals:—

$AmH^3; (CO^2)^4$
$KH^3; (CO^2)^4$
$AmCrc^3; (CO^2)^4$

$KCrc^3; (CO^2)^4$
$AmMg^3; (CO^2)^4$

$CoCoc^3; (CO^2)^4$
$(ZH^3Mn)^3,H; (CO^2)^4$

e. Oxalates with five basic radicals: $Am^4Cd; (CO^2)^5$.

f. Oxalates with six basic radicals: $Am^5Mg; (CO^2)^6$.

g. Oxalates with seven basic radicals:

$K^2Sbc^2H^2; (CO^2)^7$ | $Am^6Mg; (CO^2)^7$.

h. Oxalates with eight basic radicals: $MgMn^7; (CO^2)^8$.

i. Oxalates with ten basic radicals:

$K^3Na^2Cuc^5; (CO^2)^{10}$ | $Am^9Co; (CO^2)^{10}$.

j. Oxalates with eleven basic radicals:

$K^5Sbc^6; (CO^2)^{11}$ | $Na^5Sbc^6; (CO^2)^{11}$.

k. Oxalates with eighteen basic radicals: $Am^{13}Mg^5; (CO^2)^{18}$.

The particulars of these salts will be found in the following works:—Gmelin's Handbook of Chemistry, Vols. IX and X; Liebig's Handwörterbuch der Chemie, Band V., article Oxalsaure Salze; Gerhardt, Traité de Chimie Organique; and Liebig's Annalen for July, 1856.

The preceding Table shows that the oxalates, like the sulphates, combine with one another to produce a great variety of complex salts.

They not only produce *double salts*, as is urged by the advocates of the bibasic theory, who call the double salts, *bibasic salts*, but they produce three-fold, five-fold, seven-fold, eleven-fold, and eighteen-fold oxalates, which are by no means easy to reconcile with the bibasic theory. Nay, even the salts with an even number of acid radicals, are often more difficultly explicable on the bibasic than on the monobasic theory. Such salts are:

$$\begin{array}{l|l} \mathrm{AmCO^2} + 3(\mathrm{MgCO^2}) & \mathrm{CoCO^2} + 9(\mathrm{AmCO^2}) \\ \mathrm{Mg\,CO^2} + 7(\mathrm{MnCO^2}) & \mathrm{CoCO^2} + 3(\mathrm{Coc\,CO^2}). \end{array}$$

The formulæ of the multiple oxalates which are given in the above table, are much simpler than the formulæ that are usually ascribed to them. This is particularly the case with the salts of the BASYLIC *Metallic Radicals*, which are distinguished in the Table by the final "c" of their symbols. See page 33. How this simplification of the formulæ is effected, I have explained by an example given at page 37; but in order to leave no doubt on this subject, I will now examine one or two more examples of complex oxalates.

" Chromic oxalate forms, with the oxalates of the alkalies and earths, two series of salts, viz., dark-blue salts, which form bluish-green solutions in water, and cherry-red or garnet-coloured salts, forming cherry-red solutions in water. The formula of the blue salts is $3(\mathrm{MO,C^2O^3}) + \mathrm{Cr^2O^3,3C^2O^3} = \mathrm{C^{12}M^3Cr^2O^{24}}$; that of the red salts is $\mathrm{MO,C^2O^3} + \mathrm{Cr^2O^3,}$ $\mathrm{3C^2O^3} = \mathrm{C^8MCr^2O^{16}}$." *Gmelin, Handbook of Chemistry*, ix., 137.

Blue ammonio-chromic oxalate, $3(\mathrm{NH^4O,C^2O^3}) + \mathrm{Cr^2O^3,3C^2O^3} + 6\,\mathrm{aq}$. *Mitscherlich.* This is equal to

$$\mathrm{N^3H^{12}Cr^2C^{12}O^{24}} + \mathrm{aq^6}.$$

I consider $\mathrm{Cr^2}$ to be replaceable by $\mathrm{Crc^3}$, and I double the atomic weight of the carbon and oxygen. The number of atoms then becomes:

$$\mathrm{N^3H^{12}Crc^3C^6O^{12}} + \mathrm{aq^3}.$$

All these numbers are divisible by 3, which reduces the atoms thus:

$$\mathrm{NH^4CrcC^2O^4} + \mathrm{aq^1}.$$

This gives us $\mathrm{NH^4CO^2} + \mathrm{CrcCO^2} + \mathrm{aq}$, or $\mathrm{ZH^4,Crc;\ (CO^2)^2} + \mathrm{aq}$, which represents a double oxalate with one atom of water of crystalization. All of the blue salts are of the same construction, and belong to group *b* in the above Table.

Red ammonio-chromic oxalate, $\mathrm{NH^4O,C^2O^3} + \mathrm{Cr^2O^3,3C^2O^3} + 8\,\mathrm{aq} =$ $\mathrm{C^8(NH^4,Cr^2)O^{16}} + 8\,\mathrm{aq}$, *Gmelin*. This is equal to

$$\mathrm{NH^4Cr^2C^8O^{16}} + \mathrm{aq^8}.$$

Making the same corrections as before, this becomes

$$NH^4Crc^3C^4O^8 + Aq^4.$$

These numbers are indivisible, and the compound requires the formula:

$$NH^4CO^2 + 3(Crc,CO^2) + aq^4 = ZH^4,Crc^3;\ (CO^2)^4 + aq^4.$$

This salt is therefore a quadroxalate, and belongs to group *d* in the above Table.

Oxalate of magnesia and ammonia, with excess of the ammonia-salt. $2[C^4(2NH^4)O^8] + C^4(Mg,NH^4)O^8 + 4$ aq.

The ultimate constituents of this compound are

$$N^5H^{20}Mg^1C^{12}O^{24} + Aq^4.$$

After doubling the atomic weight of carbon and oxygen, they become

$$N^5H^{20}Mg^1C^6O^{12} + Aq^2.$$

These numbers are indivisible, and they consequently produce the compound, $(ZH^4)^5\ Mg;\ (CO^2)^6 + aq^2 = 5(ZH^4,CO^2) + Mg\,CO^2 + aq^2$; which is the salt marked group *f* in the Table; the aq^2 being neglected.

Normal oxalate of alumina. = Al^2O^3, $3C^2O^3$, *Berzelius.* = $C^{12}Al^4O^{24}$ *Gmelin.* = $C^4Al\frac{2}{3}O^8$, *Gerhardt.*

After substituting Alc^3 for Al^2 (see page 28), the formula Al^2O^3, $3C^2O^3$ becomes $Alc^3C^6O^{12}$. After doubling the atomic weight of C and O, this formula becomes $Alc^3C^3O^6$. After division by 3, we have the simple formula, $AlcCO^2$, which brings the salt into group *a*.

Oxalate of alumina and baryta. $3(BaO,C^2O^3) + (Al^2O^3,3C^2O^3) +$ 10 aq and + 30 aq. [$= C^{12}Ba^3Al^2O^{24} +$ 10 and + 30 aq.] *Gmelin.*

This salt is evidently of the same structure as the blue chromic oxalates, and is liable to a similar reduction.

$$Ba^3Al^2C^{12}O^{24} = Ba^3Alc^3C^6O^{12} = BaAlcC^2O^4.$$

Consequently the salt belongs to group *b*.

Ammonio-manganous oxalate. $C^4(NH^4,Mn)O^8 + 4$ aq, *Gmelin.* This formula is equal to $ZH^4,Mn,(CO^2)^2 + aq^2$. Group *b*.

Basic ammonio-manganous oxalate. $2NH^3 + C^4(NH^4,Mn)O^8 + C^4Mn^2O^8 + 8$ aq, *Gmelin.*

These elements may be arranged thus:

$$Z^3H^9Mn^3H^1C^8O^{16}\ H^8O^8,$$

And, after doubling the atomic weight of C and O, they become

$$Z^3H^9Mn^3H^1C^4O^8\ H^8O^4;$$

And these atoms may be grouped into a quadruple oxalate, thus:

$$\left.\begin{array}{r}\mathrm{ZH^3Mn,CO^2}\\ \mathrm{ZH^3Mn,CO^2}\\ \mathrm{ZH^3Mn,CO^2}\\ \mathrm{H,CO^2}\end{array}\right\} + \mathrm{aq^4} = \mathrm{(ZH^3Mn)^3,H\,;\,(CO^2)^4} + \mathrm{aq^4}. \quad \text{Group } d.$$

The radical ZH^3Mn is an ammonium, in which H^1 is replaced by Mn^1. The constitution of this class of azotised compounds will be explained in a subsequent section.

These examples of oxalates are sufficient to show what clear and intelligible formulæ can be given to the whole of them, when you adopt the monobasic theory and abandon the hypothesis which assumes that they contain the lumbering bases that are called sesquioxides.

NOMENCLATURE OF THE COMPLEX OXALATES.

$AmCrc\,(CO^2)^2$	Ammona chromic bicarbete.
$Ba\ Alc\,(CO^2)^2$	Baryta alic bicarbete.
$Am^2Zn\,(CO^2)^3$	Ammonen zinca tricarbete.
$AmCrc^3(CO^2)^4$	Ammona chrominic tetracarbete.
$Am^4Cd\,(CO^2)^5$	Ammonon cadma pentacarbete.
$Am^5Mg(CO^2)^6$	Ammonun magna hexacarbete.

It does not seem to be advisable to apply names to very complex oxalates; such as those contained in groups *g* to *k*.

TRIBASIC OXALATES. Besides the multiple salts of normal oxalates, there exist some others of which a brief notice may be taken. The following are tribasic salts, formed, like the tribasic phosphates, by the combination of a normal salt, with a salt on the model of water:

a. $H\,CO^2 + HHO = H^3\,CO^3$ Hydrine carbite.
b. $UcCO^2 + UcUcO = Uc^3CO^3$ Urinic carbite.
c. $PbCO^2 + PbPbO = Pb^3CO^3$ Plumbine carbite.

Salt *a* is the ordinary crystallized oxalic acid $= C^4H^2O^8 + 4$ aq, *Gmelin*. *b* is the normal uranic oxalate $= C^4(2U^2O^2)O^8$, *Gmelin*. *c* is the basic oxalate of lead $= 4PbO + C^4Pb^2O^8$, *Gmelin*.

TETRABASIC OXALATES. These are of similar constitution to the pyrophosphates—namely, they are compounds of normal oxalates with tribasic oxalates. Examples:

a. $AmCO^2 + Uc\ CO^2,UcUcO = AmUc^3,C^2O^5$ Ammona urinic carbenute.
b. $K\ \ CO^2 + Uc\ CO^2,UcUcO = KUc^3,\ C^2O^5$ Potassa urinic carbenute.
c. $AmCO^2 + H\ \ CO^2,\ \ HHO = AmH^3,\ C^2O^5$ Ammonahydrinecarbenute.
d. $Bic\,CO^2 + Bic\,CO^2,\ BicHO = HBic^3,\ C^2O^5$ Hydra bisminic carbenute.
e. $SbcCO^2 + SbcCO^2,SbcHO = HSbc^3,\ C^2O^5$ Hydra stibinic carbenute.

Usual names.—*a* = oxalate of uranyle and ammonia = $C^4(U^2O^2)(NH^4)O^8$, *Gerhardt.* *b* = oxalate of uranyle and potash = $C^4K(U^2O^2)O^8$, *Gerhardt.* *c* = acid oxalate of ammonia = $C^4(H,NH^4)O^8 + 2$ aq, *Gmelin*; sometimes called binoxalate of ammonia; in accordance with which we can, on the radical theory, write the formula thus: $AmCO^2 + HCO^2 +$ aq. There is also a quadroxalate of ammonia, which Gmelin describes as the hyperacid salt = $C^4(H,NH^4)O^8,C^4H^2O^8 + 4$ aq. This can be formulated either as a quadroxalate, thus: $AmCO^2 + 3HCO^2 + aq^2$, or as a double tetrabasic oxalate, thus:

$$\left.\begin{array}{r} AmCO^2 + HCO^2,HHO \\ HCO^2 + HCO^2,HHO \end{array}\right\} = \left\{\begin{array}{r} AmH^3,C^2O^5 \\ H^4,C^2O^5 \end{array}\right\} = AmH^7(C^2O^5)^2.$$

d = Oxalate of bismuth = $2BiO^3,2C^4O^6,2HO$.
e = Antimonic oxalate = $C^4(H,SbO^2)O^8$, *Gmelin.*

The Carbonates.

"Though but a feeble acid, the carbonic acid unites with the metallic protoxides, and forms a numerous and important class of salts which are monobasic; that is, they contain one equivalent of the acid to one equivalent of the base, like carbonate of lime (CaO,CO^2). In the case of the alkalies, a second equivalent of carbonic acid may be combined with the metallic oxide; thus with potash there is a carbonate (KO, CO^2), and a bicarbonate ($KO,HO,2CO^2$) . . . . The carbonates have considerable tendency to combine with each other, and form double salts, like dolomite, which is a double carbonate of lime and magnesia ($MgO,CO^2 + CaO,CO^2$)." — Miller, *Elements of Chemistry* (1856), ii., p. 480.

These are the common opinions of chemists concerning the carbonates.

If I double the atomic weight of carbon and oxygen, the formula for carbonate of potash becomes $KKCO^3$, that of bicarbonate of potash becomes $KHCO^3$, and that of dolomite becomes $MgCaCO^3$. In short, carbonic acid becomes BIBASIC; not bibasic in the sense in which the sulphates and oxalates are assumed to be bibasic; not endowed with a bibasicity, which is so doubtful as to require a million of plausible arguments to be advanced in support of it, and yet remain desperately uncertain after all, but bibasic in a direct sense, the truth of which is demonstrable, if you admit the atomic weight of C to be 12, and that of O to be 16.

This result of doubling the atomic weights of carbon and oxygen was pointed out to chemists by Dr. Clark in the year 1826 (see page 8), and was repeatedly urged upon their attention in my essay of 1834; yet up to this day the carbonates are assumed to be monobasic, simply because chemists will not double the atomic weights of carbon and oxygen: they will be forced to do it ultimately.

The oxalates being constituted thus: MO,CO, the carbonates are constituted thus: $MO,CO + MO$. They are consequently basic oxalates.

MO,CO = Neutral Oxalates.
$MO + (MO,CO)$ = Neutral carbonates.
$HO + (MO,CO)$ = Bicarbonates.
$MO + (MO,CO)$ = Double carbonates (dolomite, &c.).

NOMENCLATURE OF THE CARBONATES.

The names are framed on the synoptical formulæ.

1.	$CaCa, CO^3$	Calcen carbite.
2.	KH, CO^3	Potassa hydra carbite.
3.	$MgCa, CO^3$	Magna calca carbite.
4.	$BaCa, CO^3$	Baryta calca carbite.
5.	ZH^4H, CO^3	Ammona hydra carbite.
6.	$FeFe, CO^3$	Ferrenous carbite.
7.	$FeMg\ CO^3$	Ferrous magna carbite.
8.	$PbPb, CO^3$	Plumben carbite.
9.	$CecCec,CO^3$	Cerenic carbite.

Usual names.—1, Carbonate of lime. 2, Bicarbonate of potash. 3, Carbonate of lime and magnesia, or bitterspar. 4, Baryta-calcite. 5, Bicarbonate of ammonia. 6, Iron spar, or carbonate of iron. 7, Mesitine-spar. 8, White lead ore, or native carbonate of lead. 9, Ceric carbonate.

BASIC CARBONATES. The carbonates not only combine with each other, but with water, and with salts formed on the model of water, and thus produce a great variety of complicated basic salts.

EXAMPLES.

11. $ZH^4Mg,CO^3 + aq^2$. Ammona magna carbite aquete = carbonate of magnesia and ammonia,
12. $2(MgMg,CO^3)+3(CaCa,CO^3)$. Bis magnen carbite tris calcen carbite = dolomite.
13. $CaCa,CO^3 + 3(MgMg,CO^3)$. Calcen carbite tris magnen carbite = conite.
14. $CucCuc,CO^3 + CucHO$. Cuprenic carbite cum cupric hydrate = blue copper ore.
15. $CucCuc,CO^3 + 2(CucHO)$. Cuprenic carbite bis cupric hydrate = malachite.
16. $PbPb,CO^4 + PbHO$. Plumben carbite cum plumbic hydrate = white lead.

17. $PbPb,CO^3 + 2PbHO$. Plumben carbite bis plumbic hydrate = dicarbonate of lead.
18. $NaNa,CO^3 + 4(PbPbCO^3)$. Natren carbite tetrakis plumben carbite = carbonate of lead and soda.
10. $MgMgCO^3 + aq$. Magnen carbite aquate = Magnesia alba.

In some cases, the basic salts of a single metal are very numerous, and present combinations for which it is difficult to provide simple names. The following is an example of such a series :

19.	Zn^2CO^3.	Zincen carbite.
20.	$Zn^2CO^3 + Zn^3H^3O^3$.	Zincen carbite tris zinca hydrate.
21.	$Zn^2CO^3 + Zn^2H^4O^3$.	Zincen carbite cum zincen hydronite.
22.	$Zn^2CO^3 + Zn^6H^4O^5$.	Zincen carbite cum zincad hydronute.
23.	$(Zn^2CO^3)^2 + Zn^4H^6O^5$.	Bis zincen carbite cum zincon hydradute.
24.	$Zn^2CO^3 + Zn^{14}H^4O^9$.	Zincen carbite cum zincabon hydronoze.

No. 19 is the neutral carbonate of zinc, or zinc-spar; the others are basic carbonates. The water of such salts is usually reckoned apart. In these formulæ and names, the hydrogen is placed with the oxygen which is in excess of the quantity that belongs to the normal salt, and the metal is reckoned by itself. This method gives a clear account of the salts, but produces names that have an awkward appearance. Extreme convenience and extreme accuracy in nomenclature must always be difficult of combination in relation to basic salts, and chemists have to determine to what extent, and under what circumstances, convenience and accuracy shall give way to each other.

CARBONATES WITH COMPOUND POSITIVE RADICALS.

25.	$C^2H^5,C^2H^5; CO^3$	Ethylen carbite.
26.	$CH^3,C^2H^5; CO^3$	Methyla ethyla carbite.
27.	$K,C^2H^5; CO^3$	Potassa ethyla carbite.
28.	$C^5H^{11},C^5H^{11}; CO^3$	Amylen carbite.
29.	$C^2Cl^5,C^2Cl^5; CO^3$	Chlorunic-ethylen carbite.
30.	$Ba,CH^3; CO^3$	Baryta methyla carbite.
31.	$C^4H^9,C^4H^9; CO^3$	Butylen carbite.

Usual names.—25, Carbonic ether = $C^{10}H^{10}O^6$, *Gerhardt*. Carbonate of ethyl = C^4H^5O,CO^2, *Gmelin*. 26, Carbonate of ethyle and methyle, or ethyl-methyl-carbonic ether = $C^8H^8O^6$, *Gerhardt* = $C^4H^5O,CO^2 + C^2H^3O,CO^2$, *Kolbe*. 27, Carbethylate of potash = KO,C^4H^5O,C^2O^4, *Miller*. 28, Carbonate of amyl, or amylcarbonic ether = $C^{22}H^{22}O^6$, *Gerhardt*. 29, Perchlorinated carbonic ether = $C^5Cl^5O^3$, *Gmelin*. Perchlorocarbonic ether, or carbonate of perchlorinated ethyle = $C^{10}Cl^{10}O^6$, *Gerhardt*. 30, Carbomethylate of barytes. 31, Carbonate of butyle = $C^9H^9O^3 = C^8H^9O, CO^2$, *Gmelin*. Wurtz gives us the following choice of formulæ :—

$$C^{16}H^{18}O^6 \quad = \quad \begin{array}{l} \left.\begin{array}{l} C\,O \\ C^8H^9 \end{array}\right\} O^2 \\ \left.\begin{array}{l} C\,O \\ C^8H^9 \end{array}\right\} O^2 \end{array} \quad = \quad \begin{array}{l} \left.\begin{array}{l} C^8H^9 \\ C^2O^2 \end{array}\right\} O^2 \\ \left.\begin{array}{l} \\ C^8H^9 \end{array}\right\} O^2 \end{array}$$

The Chlorides.

The composition of hydrochloric acid is represented by the formula HCl; that of the ordinary neutral chlorides is represented by MCl.

Is hydrochloric acid a monobasic or a polybasic acid?

Almost every chemist will reply that it is monobasic.

Yet we find such compounds as these, $PtCl^2$ and $AuCl^3$, which are produced thus:—

$H^2,Cl^2 - H^2 + Pt \;=\; PtCl^2 + H^2$ *disengaged.*
$H^3,Cl^3 - H^3 + Au \;=\; AuCl^3 + H^3$ *disengaged.*

If the replacement of H^2 and H^3 by equivalent quantities of other positive radicals, when considered in reference to other negative radicals, constitutes the characters of *bibasicity* and *terbasicity*, why do we not give to bichlorides the title of bibasic salts, and to terchlorides the title of terbasic salts? Why are $PtCl^2$ and $AuCl^3$ not written Ptc^2Cl^2 and Auc^3Cl^3?

Most chemists take shelter from this difficulty under Dalton's law of combination in multiple properties. "It frequently happens," says Professor Miller, "that chlorine combines with the same metal in more proportions than one; for example, with iron a protochloride (FeCl) and a sesquichloride (Fe^2Cl^3) may be formed; with platinum a protochloride (PlCl) and a bichloride ($PlCl^2$) may be obtained; and generally, for each oxide of the metal which is capable of uniting with acids to form salts, a corresponding chloride exists."—*Elements of Chemistry*, ii. 520.

Gerhardt treats the question as follows:—

"The chlorides which correspond to mineral bases are monatomic, biatomic, or triatomic, according as the bases are derived from one, or two, or three, molecules of water.

a. Chlorides of monatomic bases:—

Chloride of potassium	ClK.
Chloride of silver	ClAg.
Chloride of platinosum	ClPt.

(= Protochloride of platinum.)

b. Chlorides of biatomic bases:—

Chloride of platinicum . . . . $Cl^2Pt = Cl^2 \left\{ \begin{array}{l} pt. \\ pt. \end{array} \right.$

(= Bichloride of platinum).

c. Chlorides of triatomic bases :—

Chloride of aluminium . . . . $Cl^2Al^2 = Cl^3\begin{cases}\text{al.}\\ \text{al.}\\ \text{al.}\end{cases}$

Chloride of bismuth . . . . . $Cl^3Bi = Cl^3\begin{cases}\text{bi.}\\ \text{bi.}\\ \text{bi.}\end{cases}$

Chloride of gold . . . . . . $Cl^3Au = Cl^3\begin{cases}\text{au.}\\ \text{au.}\\ \text{au.''}\end{cases}$

—*Traité de Chimie Organique*, tome iv. 712.

Gerhardt's theory appears to me to be much preferable to the theory which is commonly received by chemists, and which is expressed in the above quotation from Professor Miller. The doctrine that two, or three, and even five or seven atoms of chlorine, can combine with one atom of a metal to form a chloride, seems to rest on no good foundation. It is much simpler to suppose that every chloride is a compound of two radicals, one atom of chlorine and one atom of metal, and this view is in accordance with the constitution of most chlorides, provided we agree with the doctrine that it is possible for certain metals to form two different chemical atoms, the basylous and basylic atoms, which I have explained in the article at page 32.

This doctrine is expressed in Gerhardt's propositions, quoted above, but it is almost smothered by the "model of water" theory with which the "chloride" theory is needlessly intermixed.

The salts that are referred to by Miller and Gerhardt in the above quotations, I should formulate and name as follows :

Miller's :—	$Fe\,Cl$	$= Fe\ Cl$	. . Ferrous chlora.
—	Fe^2Cl^3	$= Fec\,Cl$	. . Ferric chlora.
—	$Pt\,Cl$	$= Pt\ Cl$	. . Platous chlora.
—	$Pt\,Cl^2$	$= Ptc\,Cl$	. . Platic chlora.
Gerhardt's :—	$Cl\ K$	$= K\ Cl$	. . Potassa chlora.
—	$Cl\ Ag$	$= Ag\ Cl$	. . Argenta chlora.
—	$Cl\ Pt$	$= Pt\ Cl$	. . Platous chlora.
—	$Cl^2\,Pt$	$= Ptc\,Cl$	. . Platic chlora.
—	$Cl^3\,Al^2$	$= Alc\,Cl$	. . Alic chlora.
—	$Cl^3\,Bi$	$= Bic\,Cl$	. . Bismic chlora.
—	$Cl^3\,Au$	$= AucCl$	. . Auric chlora.

The value of these symbols is given in the Table at page 28.

In this manner, these chlorides are all representable as monatomic chlorides, or salts of monobasic hydrochloric acid. I cannot perceive that any advantage is derived from Gerhardt's triple formulæ, such as :—

$$\mathrm{Cl}^3\left\{\begin{matrix}\text{al.}\\ \text{al.}\\ \text{al.}\end{matrix}\right.\qquad \mathrm{Cl}^3\left\{\begin{matrix}\text{bi.}\\ \text{bi.}\\ \text{bi.}\end{matrix}\right.\qquad \mathrm{Cl}^3\left\{\begin{matrix}\text{au.}\\ \text{au.}\\ \text{au.}\end{matrix}\right.$$

These symbols remind one of the arithmetic of a savage, who can only mark 3 by marking 1 three times.

The notion that every chloride is a salt containing but one atom of chlorine is, no doubt, liable to certain exceptions—such, for example, as the pentachlorides of antimony and of phosphorous, which compounds, like the pentasulphides, I confess myself unable to reconcile with the common salts of the radical theory. I do not, indeed, believe that P^5 and S^5 ever combine directly with one atom of another radical, yet I am not prepared to offer any other satisfactory explanation of this difficulty. There is a discovery yet to be made in reference to the functions of these multiples of S, Cl, and some other elements. Some kind of compound radical is probably produced, but of a kind that is not at present comprehended.

Multiple Chlorides.—The chlorides combine with each other to produce double, triple, and quadruple chlorides.

Examples of Double Chlorides.

1. $ZH^4,Cuc;\ Cl^2$ . . . . Ammona cupric chloren.
2. $ZH^3Alc,Alc;\ Cl^2$ . . . Alicam alic chloren.

Examples of Triple Chlorides.

3. Am,Mg^2,Cl^3 . . . . . Ammona magnen chlorine.
4. ZH^3Alc,Alc^2,Cl^3 . . . Alicam alenic chlorine.
5. K,Ptc^2,Cl^3 . . . . . Potassa platenic chlorine.
6. Am,Ptc^2,Cl^3 . . . . . Ammona platenic chlorine.

Usual names.—1, Protochloride of copper and ammonium, $NH^3,HCl + CuCl$, *Gmelin*. 2, See azotic radicals, No. 60. 3, Double chloride of magnesium and ammonium $= NH^4Cl,2MgCl$. 4, See azotic radicals, No. 61. 5, See platinum, No. 20. 6, See platinum, No. 22. All these triple chlorides admit of another formula, viz.,

$AmCl + 2MgCl$ = Ammona chlora bis magna chlora.

Theory of Azotic Radicals.

The radical azote combines with other radicals to produce compound positive radicals. In doing this, it controls the affinities of those radicals to such an extent, that their ordinary saturating capacities are totally paralysed, and remain so as long as the combination endures. This power of control azote exercises in two degrees.

First degree.—ONE *atom of azote* combines with TWO *radicals* to form a triple compound; which may be represented by the formula ZMM, which compound, consisting of three radicals, has a saturating power equal to that of one radical; in other words, the saturating capacities of the two radicals, MM, are paralysed, and the radical Z alone retains its saturating power.

Second degree.—ONE *atom of azote* combines with FOUR *radicals* to form a quintuple compound, which may be represented by the formula, ZMMMM; which compound, consisting of five radicals, has a saturating power equal to that of one radical; so that here again the saturating capacities of four radicals are paralysed.

The symbol M in these formulæ signifies hydrogen, or any metal, or any hydrocarbon which has, separately, the properties of a radical, either positive or negative.

The metalloids, Cl,Br,I, the element oxygen, and all nitrogenous compounds, are excluded from the number of the radicals that can combine with azote to produce the compound radicals, now under consideration. This exclusion is strictly insisted on; because many chemists allow themselves a great licence in this particular. But while Cl, Br, and I are excluded, as radicals, from among the radicals that can replace M in the compounds ZM^2 and ZM^4, it is not intended to exclude the vice-radicals of which these metalloids are constituents by substitution. See page 131. No hydrocarbons are excluded from the replacing radicals, for even those of the most powerful negative energies are capable of producing ammoniums, and lose their saturating capacities while under the domination of azote.

This governing power is exercised by azote only in these two degrees, and the products of its action are so far under the control of the chemist, that he can at pleasure experimentally convert the compound ZM^2 into the compound ZM^4, and the compound ZM^4 into the compound ZM^2; but this he can do only while the compounds are in combination with other radicals. He is unable to isolate either ZM^2 or ZM^4, and their existence is consequently not to be proved by experiment, but only to be inferred from circumstantial evidence, the nature and extent of which we proceed to take into consideration.

It is to be understood, therefore, that this "theory of the azotic radicals" is not to be a bare enumeration of facts, but is to include the exposition of a "THEORY" of the azotic radicals, and a theory, too, which differs in a great many respects from any that has hitherto been submitted to the consideration of chemists. After tracing the outline of the theory, I shall adduce a multitude of facts and examples to support it.

When an azotic radical of the first order = ZM^2 contains hydrogen only, it produces the compound ZH^2, which is commonly called *amidogen*. This term it is proposed to abridge to Amid, which is then to be made subject to the numeral terminals which have been proposed for all radicals, namely—

ZH^2.	$(ZH^2)^2$.	$(ZH^2)^3$.
Amida.	Amiden.	Amidine.

When this radical assumes the form ZHM or ZMM, it is to be considered as a Vice-Amid, or substitute for the normal amid, ZH^2.

When an azotic radical of the second order ZM^4 contains hydrogen only, it produces the compound ZH^4, which is commonly called *ammonium*. This term it is proposed to abridge to Ammon, which is to be made subject to the usual numeral terminals; thus—

ZH^4.	$(ZH^4)^2$.	$(ZH^4)^3$.
Ammona.	Ammonen.	Ammonine.

When the radical ZH^4 assumes any of the forms ZH^3M, ZH^2M^2, ZHM^3, ZM^4, it is to be considered as a Vice-Ammon, or substitute for the normal ammon ZH^4.

The symbol M in the above formulæ signifies either a metallic radical or a hydrocarbon radical.

Nomenclature of Vice-Amids and Vice-Ammons.

Since the vice-amids and vice-ammons differ from normal amid and normal ammon only by containing metallic radicals, or compound radicals, in place of hydrogen, atom for atom, it follows, that if the names of such vice-amids and vice-ammons can be made to nominate and enumerate the replacing radicals, they will give all the information that is requisite for the accurate discrimination of the respective compounds. Such a nomenclature can be arranged as follows:

A. *Discrimination af Vice-Amids.*

Case *a*. Suppose H^1 in ZH^2 to be replaced by a hydrocarbon, say phenyl C^6H^5, so as to produce the vice-amid ZH,C^6H^5. The name is to be Phenylac, where *phenyl* indicates the replacing radical; *a* shows the number of replacing atoms, and *c* is an arbitrary sign which signifies a vice-amid.

Case *b*. Suppose H^2 in ZH^2 to be replaced by two atoms of the same hydrocarbon, say $(C^6H^5)^2$, producing a vice-amid of the form Z,C^6H^5, C^6H^5, or $Z(C^6H^5)^2$. The name is to be PHENYLEC, which differs from the former only in having the letter *e* to intimate the presence of two atoms of phenyl, instead of the letter *a* to intimate a single atom.

Case *c*. When H^2 in ZH^2 are replaced by two different hydrocarbons, say Methyl CH^3 and Amyl C^5H^{11}, producing the vice-radical, Z,CH^3, C^5H^{11}. The name is to be METHYLIC-AMYLAC, where the name of the more basic of the two radicals is used as an adjective to qualify the name imposed on the vice-amid by the other more acid radical. See page 73.

Case *d*. When the replacing radical is a metal. The name is then derived from the abridged names of the metals that are given in the last column of the Table of Elements, printed at page 28. Examples:

ZHK = POTASSAC. ZHAg = ARGENTAC. ZKK = POTASSEC.

But if the replacing metal is one of those which have two different chemical atoms (the basylous and basylic atoms), the distinctive marks of those different atoms must be retained in the name of the vice-amid. See pages 33 and 87. Examples:

ZHHg = MEROUSAC. ZHHgc = MERICAC.

B. *Discrimination of Vice-Ammons.*

The vice-ammons can be distinguished from one another by a nomenclature exactly similar in principle to that which has been applied to the vice-amids, only changing the arbitrary terminal of each name from *c* to *m*.

Case *e*. The vice-ammon is represented by the formula ZH^3,C^2H^3. Name: ACETYLAM. This name indicates an ammonium in which one atom of hydrogen is replaced by one atom of acetyl = C^2H^3. Any other hydrocarbon may occur in place of acetyl. This is the most numerous and most important class of the vice-ammons.

Case *f*. The replacing radical is a metal. Formula: ZH^3Ag. Name: ARGENTAM.

Case *g*. The replacing radical is a basylous metal. Formula: ZH^3Cu. Name: CUPROUSAM.

Case *h*. The replacing radical is a basylic metal. Formula: ZH^3Ptc. Name: PLATICAM.

Case *i*. The replacement of H^1,H^2,H^3,H^4, in ZH^4, by a similar number of other radicals, produces a series of compounds which require names of the following forms; methyl is taken as an example, but any other radical may occur instead.

ZH^3,CH^3.	*Name*:—	METHYLAM.
$ZH^2(CH^3)^2$.	—	METHYLEM.
$ZH\ (CH^3)^3$.	—	METHYLIM.
$Z\ \ (CH^3)^4$.	—	METHYLOM.

Case *k*. When the hydrogen in ZH^4 is replaced by two different radicals. The names are regulated in this case on the principle that has been described under case *c*.

Examples:—

$Z,CH^3,(C^2H^5)^3$.	*Name*:—	METHYLIC-ETHYLIM.	(*a*.)
ZH^2,C^2H^3,C^6H^5.	—	ACETYLIC-PHENYLAM.	(*b*.)
ZH,C^2H^5,C^2H^5,C^7H^7.	—	TOLUENYLIC-ETHYLEM.	(*c*.)

The name (*a*) intimates that the vice-ammon is an ammonium in which H^3 have been replaced by three atoms of ethyl $(C^2H^5)^3$, and which would therefore simply require the name *ethylim*; but, as the fourth atom of hydrogen has been replaced by methyl CH^3, it is necessary to qualify the name of the vice-ammon by the prefix *methylic-*. In like manner, the name (*b*) intimates the modification that is made in a *phenylam*, or an ammonium that contains one atom of phenyl, by the replacement of another atom of its hydrogen by *acetyl*. Finally, the name (*c*) intimates that the vice-ammon contains two atoms of ethyl and one atom of toluenyl. In this case, the name of the single atom is used to qualify the name afforded by the two atoms. This is with a view to simplicity in nomenclature. But as toluenyl is an acid radical, this practice is contrary to the rule laid down under case *c*; to which rule, however, it is easy to conform by describing ZH,C^2H^5,C^2H^5,C^7H^7 as ethylenic-toluenylam.

Case *l*. When a vice-ammon contains more than two kinds of radicals besides hydrogen, the name must at present consist of a mere enumeration of its constituents.

Examples:—

$Z,CH^3,C^2H^5,C^2H^5,\ C^5H^{11}$.	*Name*:—	Zot-methyla-ethylen-amyla.
$Z,CH^3,C^2H^5,C^5H^{11},C^6H^5$.	—	Zot-methyla-ethyla-amyla-phenyla.

The name now applied to $Z,CH^3,C^2H^5,C^2H^5,C^5H^{11}$ is methylodiethylamylammonium, so that in this case, the new nomenclature is merely not retrograding. When we know a greater number of the compounds of this class, we may be able to form a more compendious nomenclature for them.

The terminals applied to the names of zotic radicals can never be mistaken for those that are recommended to be applied to radicals proper, or to oxidised radicals. See page 86. The names are therefore not only short, but in every case exact and free from doubt.

For the sake of the convenience which is afforded when we can speak of different classes of compounds in general terms, it is proper to add the following definitions:—

Amid is the normal compound ZH^2. The vice-amids are of two kinds; *amidacs*, in which H^1 is replaced by another radical = ZHM; and *amidecs* in which H^2 are replaced by two other radicals = ZMM.

Ammon is the normal ammonium ZH^4, with which the common symbol Am is equivalent. The vice-ammons are of four kinds:

Ammonam = ZH^3M.
Ammonem = ZH^2M^2.
Ammonim = ZHM^3.
Ammonom = ZM^4.

When M in these formulæ is replaced by the symbol of a compound radical, the words amid and ammon in the corresponding names, are to be replaced by the names of the replacing radicals. Thus:—

ZH,C^6H^5 = Phenylac.
$Z(C^5H^{11})^2$ = Amylec.
ZH^3,C^6H^5 = Phenylam.
$Z(C^5H^{11})^4$ = Amylom.

RELATION OF THE AMIDS TO THE AMMONS.

The amids and ammons of every description usually act in salts as positive radicals. The basic properties of the ammons are stronger than those of the amids; hence the amids can act as negative radicals towards the ammons. Different amids can also act as negative and positive radicals towards one another. Generally, but not always, nor necessarily, the salts of the amids with oxygen acids, contain one atom less of oxygen than is contained in the corresponding salts formed by the ammons. The reason of this is, that the governing power of the azote is, so to speak, expansive and contractive, and can be made, at the will of the chemist, to control either MM or MMMM; in consequence of which property, the salts of the amids and ammons are reciprocally convertible the one into the other by reactions that are expressed in the following equations:—

(*a*.) $(ZMMMM)O + RO = [(ZMM) + RO] + M,MO$;
or, synoptically, $ZM^4,RO^2 = ZM^2,RO + M,MO$.

(*b*.) $[(ZMM) + RO] + M,MO = (ZMMMM)O + RO$;
or, synoptically, $ZM^2,RO + M,MO = ZM^4,RO^2$.

where R signifies any acid radical; M = H or any equivalent of H.

In reaction *a*, two radicals are removed from the salt in company with one atom of oxygen. The salt is thereby reduced to a lower degree of oxidation, and the ammon is converted into an amid. In reaction *b*, the operation is reversed.

Conversion of Ammons into Amids.

These equations may be illustrated by a special example :—

Let ZH^4 = Ammonium.	Let H,CO^2 = Oxalic acid.
ZH^2 = Amidogen.	H,HO = Water.

The radical ZH^4 can be made to displace the radical H in oxalic acid H,CO^2, and to produce the salt ZH^4,CO^2, or, as it may be expressed in an analytical formula, ZH^4O,CO. This salt is commonly called oxalate of ammonia, or oxalate of oxide of ammonium. By an experiment, the details of which do not belong to the question under consideration, the oxalate of ammonia can be decomposed into two other salts, thus :—

$$\underbrace{ZH^4O + CO}_{\text{Oxalate of Ammonia.}} = \underbrace{ZH^2,CO}_{\text{Oxamid.}} + \underbrace{H,HO.}_{\text{Water.}}$$

In oxalate of ammonia we have a salt that is NOT *formed on the model of water ;* for whereas water contains one oxidised radical and one unoxidised radical, this salt contains two oxidised radicals. In process *a*, one of these radicals, ZH^4, is split up, by chemical means, into three radicals, $ZH^2,H,H,$; and these three radicals, with the single atom of carbon and the two atoms of oxygen, produce two salts that are really formed on the model of water; one of them being actually water H,HO, and the other a salt whose structure is similar to that of water ZH^2,CO. This salt is commonly called *oxamid.* In accordance with the proposed new nomenclature, it would be called AMIDA CARBATE; this name serving to indicate one atom of unoxidised amidogen acting as a basic radical against one atom of carbon, acting as an acid radical in combination with one atom of oxygen. The doctrine of the formation of salts on the model of water is particularly valuable in aiding the explanation of the precise action of the azotic radicals. There cannot be the least doubt that as water is the hydrate of hydrogen = $H + HO$, namely, a salt containing two radicals, so oxamid is the carbate of amidogen = $ZH^2 + CO$, also a salt containing two radicals; and as this explanation of the equation *a* applies, not only to salts of normal amidogen and normal ammonium, but to salts of all the varieties of vice-amids and vice-ammons, it is of great importance.

Conversion of Amids into Ammons.

In regard to equation *b*), it needs only to be remarked, that the explanation of it is, like the formula, only the inversion of that of equation *a*). When oxamid ZH^2,CO is subjected, by proper chemical means, to the action of H,HO, the governing power of Z is enlarged, the nonoxidised amid ZH^2 becomes reconverted into the oxidised ammon ZH^4O, and the original salt, the oxalate of ammonia, ZH^4O,CO or ZH^4,CO^2, is thoroughly reconstituted.

Double Salts containing Ammons and Amids.

The salts of the amids and the salts of the ammons have a great tendency to combine with one another, and thus to produce double salts. Hence, oxamid ZH^2,CO combines with oxalate of ammonia ZH^4,CO^2, to produce the double salt which is represented by the following formulæ:—

$$\left\{\begin{matrix} ZH^2,CO \\ ZH^4,CO^2 \end{matrix}\right\} = ZH^4,ZH^2;\ C^2O^3.$$

This salt is commonly called oxamate of ammonia, in consequence of the prevalence of a notion that it is the ammonia-salt of an acid which is called OXAMIC ACID, and which acid is *assumed to contain amidogen as* PART *of its Acid Radical.* The radical theory repudiates the idea that any acid radical can contain amidogen as one of its constituents, and according to the radical theory, oxamic acid is a double salt, consisting of oxamid and hydrated oxalic acid, thus:—

	ZH^2,CO	+	H^r,CO^2	=	$H^r,ZH^2;\ C^2O^3$.
Present Names.	Oxamid	+	Oxalic acid	=	Oxamic acid.
Proposed Names.	Amida carbate	+	Hydra carbete	=	Hydra amida carbenite.

In these formulæ, H^r signifies an atom of hydrogen that is replaceable by a positive radical, either a metal or a hydrocarbon.

This double salt can, like oxamid, have its unoxidised amid experimentally enlarged by the addition of HHO to oxidised ammon; the consequence of which enlargement is, that the so-called oxamic acid is converted into binoxalate of ammonia. Thus:—

$$H^r,ZH^2;\ C^2O^3, \text{ or } \left\{\begin{matrix} ZH^2,CO \\ H\ ,CO^2 \end{matrix}\right\} + HHO = \left\{\begin{matrix} ZH^4,CO^2 \\ H\ ,CO^2. \end{matrix}\right.$$

What has been said here respecting the metamorphoses of the ammon and amid of a salt that has carbon for its acid radical, is equally true of salts that have negative hydrocarbons for their acid radicals; of which fact numerous examples will appear in the following Tables:—

NOMENCLATURE OF THE DOUBLE SALTS OF AMIDS AND AMMONS.

The name of a double salt which contains a salt of an amid combined either with a neutral salt of an ammon, or of any single radical, may be framed either on the analytical formula or the synoptical formula. The latter gives the most compendious name, and will be generally used.

Examples:—

a. Where the Acid Radical is Carbon.

$H, ZH^2; C^2O^3$ = Hydra amida carbenite.
$ZH^4, ZH^2; C^2O^3$ = Ammona amida carbenite.
$Ag, ZH^2; C^2O^3$ = Argenta amida carbenite.
$CH^3, ZH^2; C^2O^3$ = Methyla amida carbenite.

b. Where the Acid Radical is a Hydrocarbon.

$H, ZH^2; (C^2H^2)^2O^3$ = Hydra amida succinylenite.
$Ag, ZH^2; (C^2H^2)^2O^3$ = Argenta amida succinylenite.
$H; ZH, C^6H^5; (C^5H^7)^2O^3$ = Hydra phenylac camphorylenite.

The analytical formula of the last salt is as follows:—

$$ZH, C^6H^5; C^5H^7O + H, C^5H^7O^2.$$

Name:—Phenylac camphorylate cum Hydra camphorylete.

Some of the salts that contain amids are volatile. None of the salts that contain ammons are volatile. Some of the double salts that contain both amids and ammons are volatile; but they have not yet been thoroughly examined.

GASEOUS SALTS OF AMIDOGEN.

In the preceding development of the theory of the azotic radicals, the word ammonia has been intentionally avoided. But it it is now time to explain what is meant by that word, and I commence by requesting the reader to examine the notice of ammonia that has been already given at page 99. It is there stated, and it is to be here repeated, that ammonia is *not a radical*, but a SALT. Its composition is commonly represented by the formula NH^3. M. Gerhardt gives it as

$$N\left\{\begin{array}{l}H\\H\\H\end{array}\right.$$

In accordance with the present theory, it is $ZH^2 + H$, which formula represents it to be a *salt*; namely, a hydride of the radical ZH^2. This salt—ammonia—has, in the state of gas, an atomic measure of *two volumes*, which in itself is almost a proof, and certainly affords a strong presumption, that the gas is a compound of *two radicals*. All the volatile hydrides of vice-amids, which are represented at page 99, agree with ammonia in this characteristic property of having an atomic measure of

This theory a Cooke's series recieve important support from each other ~~The~~ atomic weight of NH_4 cannot be brought under the form $1+n3$ but that of NH_3 easily can be.

two volumes, and there is probably no exception to this general rule. It is reasonable to infer, therefore, that all the hydrides of vice-amids are, like ammonia, not radicals, but salts—*compounds of two radicals.*

In page 100, another table is given of a series of the gaseous compounds, which are commonly called salts of ammonia, of which salts, the one named sal-ammoniac, or hydrochlorate of ammonia, may be taken as the model. These salts have each, in the gaseous state, an atomic measure of four volumes, which is an indication of the presence of four radicals, or the constituents necessary to produce a double salt in each compound. When we examine the formula of sal-ammoniac, we find it to be $ZH^2,H + H,Cl$. We have here the whole materials of two salts, the hydride of amidogen, which of itself is known to measure two volumes, and the hydride of chlorine, or hydrochloric acid, which also is known to measure two volumes. These two salts, known to exist separately, and each having the measure of two volumes, combine without condensation to produce the double salt, the hydrochlorate of ammonia, which has consequently an atomic measure of four volumes, because it is a compound of four radicals $= (ZH^2 + H) + (H + Cl)$.

But upon this explanation there follows a difficulty. When sal-ammoniac is brought into the state of solid crystals, it forms a compound which, in its form, and in many of its chemical characters, closely agrees with the salt that is called chloride of potassium. Now, chloride of potassium is considered to be a direct compound of potassium with chlorine, a *binary* compound in accordance with the formula KCl; and we have to account for the peculiar circumstance, how it is, that a compound of two radicals, a simple salt $= KCl$, should appear to be the counterpart of a salt, the gaseous properties of which indicate it to be a double salt of the formula $ZH^2,H + H,Cl$. The only rational explanation of this difficulty seems to be, that the elements which constitute sal-ammoniac form in fact, under different circumstances, two *different salts.* In the gaseous state, they produce a double salt—the hydrochlorate of ammonia $= ZH^2,H + H,Cl$, and in the solid and aqueous states they produce a simple salt = the chloride of ammonium, $ZH^4 + Cl$. In other words, the gaseous salt contains amidogen, and the solid salt contains ammonium. In the solid state, the government of azote is exercised over H^4; in the gaseous state it is limited to H^2. Admitting the facts, that the salts of the vice-amids are frequently volatile, and those of the vice-ammons are always fixed, this explanation is quite in accordance with our experimental evidence, and approaches as nearly to demonstration as circumstantial evidence can be reasonably expected to do.

SALTS OF AMMONIUM.

The theory which I have just explained applies to all the compounds that are commonly called salts of Ammonia and Ammonium; in fact to all the salts that are formed by the combination of ammonia with hydrated acids, whether oxidised or non-oxidised. Thus it applies to the following salts:—

	Proposed Names.	Present Names.	
ZH^4,Cl	= Ammona chlora	= Chloride	of Ammonium.
ZH^4,Br	= Ammona broma	= Bromide	
ZH^4,I	= Ammona ioda	= Iodide	
ZH^4,Cy	= Ammona cyana	= Cyanide	
ZH^4,SO^2	= Ammona sulphete	= Sulphate	of Ammonia.
ZH^4,NO^3	= Ammona nitrite	= Nitrate	
ZH^4,CO^2	= Ammona carbete	= Oxalate	
$ZH^4,C^2H^3O^2$	= Ammona acetylete	= Acetate	

The salts that are produced by the combination of ammonia with anhydrous oxygen acids will be described in the course of the following investigation.

AMMONIATED SALTS.

Under the head of ammoniated salts, chemists commonly place a series of compounds which have not been alluded to in the preceding theory. They consist of neutral salts, either of hydracids or oxacids, combined with two atoms of ammonia. The following are examples of such salts expressed in the formulæ in common use:—

a. Ammoniated chloride of silver $= AgCl + 2H_3N.$
b. Ammoniated nitrate of silver $= AgO,NO_5 + 2H_3N.$
c. Ammoniated sulphate of copper $= CuO,SO_3 + 2H_3N.$

[In these formulæ $O = 8$.]

The formulæ provided for these compounds by the theory now under discussion are as follow:—

a. $ZH^3Ag,Cl + ZH^2,H$ = Argentam chlora cum Amida hydra.
b. $ZH^3Ag,NO^3 + ZH^2,H$ = Argentam nitrite cum Amida hydra.
c. $ZH^3Cuc,SO^2 + ZH^2,H$ = Cupricam sulphete cum Amida hydra.

According to the new theory, these compounds are all regular double salts. Half the ammonia converts the metal of each salt into an ammonam. The other half combines as a salt, the hydride of amidogen, with the ammonium salt, to produce a compound salt. This method of explanation will be found to clear away a variety of difficulties which accompany the ordinary theories respecting the compound mercury and platinum bases. See the section on salts of platousam.

Examples of Azotic Radicals.

Having briefly explained the proposed theory of azotic radicals, I proceed to support its principles, and develop its details, by adducing a number of examples.

The salts which contain azotic radicals are so numerous and varied, and they figure in chemical books under so many different names and formulæ, and are made the foundation of so much classification and theorizing, that it is difficult to compress a lucid account of them into the narrow space which is necessarily allotted to them in this Essay.

I have to prove that the proposed theory is of general applicability; that its formulæ are accurate; and that its nomenclature is sufficiently flexible and comprehensive to answer the purpose for which it is recommended.

This proof requires a considerable number of examples. I have collected nearly a thousand. They do not by any means constitute a complete catalogue of the salts of the azotic radicals, but they afford specimens of the most characteristic varieties. I have arranged them in groups which will exhibit the different classes of salts of the azotic radicals. I have given them the names and formulæ that are demanded by the radical theory, and I have added a series of explanatory notes, which contain the ordinary names and formulæ of the selected salts, and serve not merely to identify them, but to lead to the discussion of a series of knotty questions respecting azotic radicals, upon which at present the opinions of chemists are either divided or unsettled.

These notes will, however, neither depict all the formulæ, nor recite all the synonymes, which the ingenuity of chemists has contrived for these so-called "organic bases," which substances infinitely exceed all other chemical compounds in the variety of the fancy costumes in which they have been made to masquerade.

Ammonias.

SECTION 1.—AMMONIAS, in WHICH H^1 IS REPLACED by ANOTHER RADICAL. HYDRIDES of AMIDACS.

1. $ZH,C^5H^{11}; H$ . . . Amylac hydra.
2. $ZH,C^2H^3; H$ . . . Acetylac hydra.
3. $ZH,C^4H^9; H$ . . . Butylac hydra.
4. $ZH,C^8H^{13}; H$ . . . Conylac hydra.
5. $ZH,C^9H^{11}; H$ . . . Cumenylac hydra.
6. $ZH,C^2H^5; H$ . . . Ethylac hydra.
7. $ZH,C^2H^3I^2; H$ . . . Iodenic-ethylac hydra.
8. $ZH,C\ H; H$ . . . Formylac hydra.
9. $ZH,C^9H^5; H$ . . . Leukylac hydra.

10.	$ZH,CH^3; H$	Methylac hydra.
11.	$ZH,C^{10}H^7; H$	Naphtylac hydra.
12.	$ZH,Na; H$	Natrac hydra.
13.	$ZH,C^8H^{17}; H$	Octylac hydra.
14.	$ZH,C^6H^5; H$	Phenylac hydra.
15.	$ZH,C^6H^4Cl; H$	Chloric-phenylac hydra.
16.	$ZH,C^6H^3Cl^2; H$	Chlorenic-phenylac hydra.
17.	$ZH,C^6H^4Br; H$	Bromic-phenylac hydra.
18.	$ZH,C^6H^3B^2; H$	Bromenic-phenylac hydra.
19.	$ZH,C^6H^4I; H$	Iodic-phenylac hydra.
20.	$ZHK; H$	Potassac hydra.
21.	$ZH,C^3H^7; H$	Propylac hydra.
22.	$ZH,C^7H^7; H$	Toluenylac hydra.
23.	$ZH,C^5H^9; H$	Valerylac hydra.
24.	$ZH,C^8H^9; H$	Xylenylac hydra.

Section 2.—Ammonias in which H^2 are replaced by other Radicals.

A). Amidacs combined with Acid Radicals.

25.	$ZH,C^2H^5; C^2H^3$.	Ethylac acetyla.
26.	$ZH,C^6H^5; C^7H^5$.	Phenylac benzyla.
27.	$ZH,C\,H^3; C^2H^5$.	Methylac ethyla.
28.	$ZH,C^2H^3; C^6H^5$.	Acetylac phenyla.
29.	$ZH,C^5H^{11}; C^6H^5$.	Amylac phenyla.
30.	$ZH,C^2H^5; C^6H^5$.	Ethylac phenyla.
31.	$ZH,C^2H^5; C^6H^4Cl$	Ethylac chloric-phenyla.
32.	$ZH,C\,H^3; C^6H^5$.	Methylac phenyla.
33.	$ZH,\quad K; C^6H^5$.	Potassac phenyla.
34.	$ZH,C^2H^5; C^3H^7$.	Ethylac propyla.
35.	$ZH,C^2H^5; C^7H^7$.	Ethylac toluenyla.

B). Hydrides of Amidecs.

36.	$Z,C^5H^{11},C^5H^{11}; H$	Amylec hydra.
37.	$Z,C^2H^5,C^2H^5; H$	Ethylec hydra.
38.	$Z,CH^3,CH^3; H$.	Methylec hydra.
39.	$Z,C^3H^7,C^3H^7; H$	Propylec hydra.

Section 3.—Ammonias in which H^3 are replaced by other Radicals.

Salts of Amidecs.

a. The three Radicals are unlike.

40.	$Z,C\,H^3,C^2H^5; C^5H^{11}$	Methylic-ethylac amyla.
41.	$Z,C^2H^5,C^5H^{11}; C^6H^5$.	Ethylic-amylac phenyla.
42.	$Z,C\,H^3,C^2H^5; C^6H^5$.	Methylic-ethylac phenyla.

b. The three Radicals are alike.

43.	$Z,C^5H^{11},C^5H^{11}; C^5H^{11}$ . .	Amylec amyla.
44.	$Z,C^{16}H^{33},C^{16}H^{33}; C^{16}H^{33}$ . .	Cetylec cetyla.
45.	$Z,C^2H^5, C^2H^5 ; C^2H^5$ . .	Ethylec ethyla.
46.	$Z,CH^3,CH^3 ; CH^3$	Methylec methyla.
47.	Z Cu,Cu ; Cu	Cuprousec cuprous.
48.	Z Hgc,Hgc ; Hgc	Mericcec meric.
49.	Z K,K ; K	Potassec potassa.

c. Two basic and one acid Radical.

50.	$Z,C^2H^5, C^2H^5 ; C^5H^{11}$ . . .	Ethylec amyla.
51.	$Z,C^5H^{11},C^5H^{11}; C^2H^5$ . . .	Amylec ethyla.
52.	$Z,C^2H^5, C^2H^5 ; C H^3$ . . .	Ethylec methyla.
53.	$Z,C^5H^{11},C^5H^{11}; C^6H^5$ . . .	Amylec phenyla.
54.	$Z,C^2H^5, C^2H^5 ; C^6H^5$ . . .	Ethylec phenyla.
55.	$Z,C^2H^5, C^2H^5 ; C^6H^4Cl$ . .	Ethylec chloric-phenyla.
56.	$Z,C^2H^5, C^2H^5 ; C^7H^7$ . . .	Ethylec toluenyla.

USUAL NAMES AND FORMULÆ OF THE AMMONIAS.

No. 1. $ZH,C^5H^{11}; H$ is commonly denoted by one of the three following formulæ :—

$$C^{10}H^{13}N, \text{ or } C^{10}H^{11},H^2N, \text{ or } N\left\{\begin{array}{l} C^{10}H^{11} \\ H \\ H \end{array}\right.$$

These three formulæ (in which C = 6) may be taken as models of the formulæ that are usually given to the ammonias Nos. 1 to 24 in the list, and it is consequently needless to quote them all. In the same way, the ammonias have not only a variety of formulæ, but a variety of names; No. 1, for example, being called amylamine, amylia, and azoture (or nitride) of amyl and of hydrogen. I shall, for the sake of brevity, only quote such of these names as serve either to identify the compounds, or to exhibit some of the vagaries of chemists, or to illustrate important or disputed doctrines :—1, Amylamine. 2, Acetylamine; acetylia. 3, Butylamine; butyria; tetrylia. 4, Conine; conia. 5, Cumidine. 6, Ethylamine; ethylia. 7, Iodethylamine. 8, Formylia. 9, Leukol; quinoline. 10, Methylamine; methylia. 11, Naphtylamine. 12, Azoture of sodium and hydrogen. 13, Octylia; caprylia. 14, Aniline; phenylamine; phenylia; phenylamide; crystalline; krystallin; kyanol; benzidam. 15, Chloraniline. 16, Bichloraniline. 17, Bromaniline. 18, Bibromaniline. 19, Iodaniline. 20, Amidide of potassium. 21, Propylamine; tritylia; tritylamine; metacetamine; œnylamine. 22, Toluidine. 23, Piperidine. 24, Xylidine.

25, Ethyl-acetylia. 26, Benz-anilide. 27, Methyl-ethylamine. 28, Phenylacetylia. 29, Amylophenylamine; amylaniline. 30, Ethylaniline, ethyphenylamine. 31, Ethyl-chloraniline. 32, Methylaniline. 33, Anilide of potassium. 34, Ethyl-propylamine. 35, Ethyl-toluidine.

36, Diamylamine. 37, Diethylamine; diethylia. 38, Dimethylamine; dimethylia. 39, Dipropylamine.

40, Methyl-ethyl-amylamine. 41, Ethyl-amylo-phenylamine. 42, Methyl-ethylo-phenylamine. 43, Triamylamine; triamylia. 44, Tricetylia; tricetylamine. 45, Triethylamine. 46, Trimethylamine. 47, Azoture of cuprosum. 48, Nitride of mercury. 49, Azoture of potassium.

50, Biethylo-amylamine. 51, Biamylo-ethylamine. 52, Methyl-diethylamine. 53, Diamylo-phenylamine. 54, Biethylaniline. 55, Biethyl-chloraniline. 56, Diethyltoluidine.

Salts of Vice-Ammons.

The following is a list of Salts of VICE-AMMONS; that is to say, of Salts of Ammonium, in which the Hydrogen has been more or less replaced by other Radicals.

GROUP A. AMMONAMS = ZH^3M.

57. $ZH^3,C^2H^3; Cl$	Acetylam chlora.
58. $ZH^3,C^2H^3; HO$	Acetylam hydrate.
59. $ZH^3,Alc; Cl$	Alicam chlora.
60. $ZH^3,Alc; Cl + AlcCl$ . .	Alicam chlora cum alic chlora.
61. $ZH^3,Alc; Cl + 2AlcCl$.	Alicam chlora bis alic chlora.
62. $ZH^3,Ag; C^6H^3O^3$ . . .	Argentam indylite.
63. $ZH^3,Ag; CrO^2 + ZH^2H$.	Argentam chromete cum amida hydra.
64. $ZH^3Ba; C^6H^3O^3$ . . .	Barytam indylite.
65. $ZH^3,C^4H^9; Cl$	Butylam chlora.
66. $ZH^3,Coc; CO^2 + ZH^2H$.	Cobalticam carbete cum amida hydra.
67. $ZH^3,Cuc; CO^2$	Cupricam carbete.
68. $ZH^3,Cuc; CO^2 + CucCO^2$	Cupricam carbete cum cupric carbete.
69. $CucCO^2 + ZH^4,CO^2$ . .	Cupric carbete cum ammona carbete.
70. $ZH^3,C^2H^5; CO^2$	Ethylam carbete.
71. $ZH^3,C^2H^5; HO$	Ethylam hydrate.
72. $ZH^3,C^2H^5; Cl$	Ethylam chlora.

73.	$ZH^3,C^2H^5;\ Br$	Ethylam broma.
74.	$ZH^3,C^2H^5;\ Cl + 3AucCl$	Ethylam chlora tris auric chlora.
75.	$ZH^3,C^2H^5;\ Cl + HgcCl$	Ethylam chlora cum meric chlora.
76.	$ZH^3,CH^3;\ CO^2$	Methylam carbete.
77.	$ZH^3,CH^3;\ CO^2 + HCO^2$	Hydra methylam bicarbete.
78.	$ZH^3,CH^3;\ Cl$	Methylam chlora.
79.	$ZH^3,CH^3;\ Br$	Methylam broma.
80.	$ZH^3,CH^3;\ I$	Methylam ioda.
81.	$ZH^3,CH^3;\ Cl + HgcCl$	Methylam chlora cum meric chlora.
82.	$ZH^3,CH^3;\ Cl + 3AucCl$	Methylam chlora tris auric chlora.
83.	$ZH^3,C^{10}H^7;\ Cl$	Naphtylam chlora.
84.	$ZH^3,C^{10}H^7;\ Br$	Naphtylam broma.
85.	$ZH^3,C^{10}H^7;\ I$	Naphtylam ioda.
86.	$ZH^3,Ni;\ CO^2 + NiCO^2$	Nicollousam carbete cum nicollous carbete.
87.	$ZH^3,C^6H^5;\ CO^2$	Phenylam carbete.
88.	$ZH^3,C^6H^4Br;\ CO^2$	Bromic-phenylam carbete.
89.	$ZH^3,C^6H^4I;\ CO^2$	Iodic-phenylam carbete.
90.	$ZH^3,C^6H^5;\ Br$	Phenylam broma.
91.	$ZH^3,C^6H^5;\ Cl$	Phenylam chlora.
92.	$ZH^3,C^6H^5;\ I$	Phenylam ioda.
93.	$ZH^3,C^6H^4Br;\ Cl$	Bromic-phenylam chlora.
94.	$ZH^3,C^6H^4Cl;\ Cl$	Chloric-phenylam chlora.
95.	$ZH^3,C^6H^4I;\ Cl$	Iodic-phenylam chlora.
96.	$ZH^3,C^6H^5;\ Cl + 2PtcCl$	Phenylam chlora bis platic chlora.
97.	$ZH^3,C^6H^5;\ PO^3$	Phenylam phosphite.
98.	$(ZH^3,C^6H^5)^2,H;\ PO^4$	Phenylamen hydra phosphote.
99.	$ZH^3,C^6H^5;\ H^2;\ PO^4$	Phenylam hydren phosphote.
100.	$(ZH^3,C^6H^5)^2,H^2;\ P^2O^7$	Phenylamen hydren phospheneze.
101.	$ZH^3,K;\ C^8H^5O^2$	Potassam indylite.
102.	$ZH^3,C^7H^7;\ Cl$	Toluenylam chlora.
103.	$ZH^3,C^7H^7;\ Cl + 2PtcCl$	Toluenylam chlora bis platic chlora.
104.	$ZH^3,C^7H^7;\ Cl + 3AucCl$	Toluenylam chlora tris auric chlora.
105.	$ZH^3,C^7H^7;\ CO^2 + HCO^2$	Hydra toluenylam bicarbete.

GROUP B. AMMONEMS = ZH^2M^2.

106.	$ZH^2,Hgc^2;\ Cl$	Mericcem chlora.
107.	$ZH^2(CH^3)^2;\ I$	Methylem ioda.

108. $ZH^2,C^2H^5,C^{10}H^7$; I	Ethylic-naphtylam ioda.
109. ZH^2,Hgc,C^6H^5; Cl	Meric-phenylam chlora.
110. $ZH^2(C^7H^5)^2$; HO	Benzylem hydrate.
111. ZH^2,C^2H^5,C^6H^5; Br	Ethylic-phenylam broma.
112. ZH^2,C^2H^5,C^7H^7; Cl + 2PtcCl	Ethylic-toluenylam chlora bis platic chlora.

GROUP C. AMMONIMS = ZHM^3.

113. $ZH,(C^5H^{11})^3$; Cl	Amylim chlora.
114. $ZH,(CH^3)^3$; I	Methylim ioda.
115. ZH,C^2H^5,C^2H^5,C^6H^5; Br	Phenylic-ethylem broma.
116. ZH,C^2H^5,C^2H^5,C^7H^7; I	Toluenylic-ethylem ioda.
117. $ZH,C^2H^5,C^2H^5,C^5H^{11}$; Cl + 2PtcCl	Amylic-ethylem chlora bis platic chlora.

GROUP D. AMMONOMS = ZM^4.

118. ZH^4; HO	Ammona hydrate.
119. ZH^4; Cl	Ammona chlora.
120. ZH^4; CO^2	Ammona carbete.
121. ZH^4; H; $(CO^2)^2$	Hydra ammona bicarbete.
122. ZH^4; H^3; $(CO^2)^4$	Hydrine ammona tetracarbete.
123. ZH^4; $C^8H^3O^3$	Ammona indylite.
124. $Z(C^5H^{11})^4$; I	Amylom ioda.
125. $Z(C^5H^{11})^4$; HO	Amylom hydrate.
126. $Z(C^2H^5)^4$; Cl	Ethylom chlora.
127. $Z(C^2H^5)^4$; I	Ethylom ioda.
128. $Z(C^2H^5)^4$; HO	Ethylom hydrate.
129. $Z(C^2H^5)^4$; Cl + 2PtcCl	Ethylom chlora bis platic chlora.
130. $Z(C^2H^5)^4$; Cl + 3AucCl	Ethylom chlora tris auric chlora.
131. $Z(CH^3)^4$; I	Methylom ioda.
132. $Z(CH^3)^4$; HO	Methylom hydrate.
133. $Z(CH^3)^4$; Cl + 2PtcCl	Methylom chlora bis platic chlora.
134. $ZHgc^4$; CO^2	Mericom carbete.
135. $Z(C^2H^5)^3,C^5H^{11}$; I	Amylic-ethylim ioda.
136. $Z(C^2H^5)^3,C^5H^{11}$; HO	Amylic-ethylim hydrate.
137. $Z(C^2H^5)^3,C^5H^{11}$; Cl + 2PtcCl	Amylic-ethylim chlora bis platic chlora.
138. $Z(C^2H^5)^3,C^6H^5$; HO	Phenylic-ethylim hydrate.
139. $Z(C^2H^5)^3,C^7H^7$; HO	Toluenylic-ethylim hydrate.
140. $Z(C\ H^5)^3,C^7H^7$; Cl + 2PtcCl	Toluenylic-ethylim chlora bis platic chlora.

141. $ZCH^3,(C^2H^5)^3$; I	Methylic-ethylim ioda.
142. $ZCH^3,C^2H^5,C^2H^5, C^5H^{11}$; I	Zot-methyla-ethylen-amyla ioda.
143. $Z,CH^3,C^2H^5,C^2H^5,C^5H^{11}$; Cl + 2PtcCl	Zot-methyla-ethylen-amyla chlora bis platic chlora.
144. $Z,CH^3,C^2H^5,C^5H^{11},C^6H^5$; I	Zot-methyla-ethyla-amyla-phenyla ioda.
145. $Z,CH^3,C^2H^5,C^5H^{11},C^6H^5$; HO	Zot-methyla-ethyla-amyla-phenyla hydrate.
146. $Z,CH^3,C^2H^5,C^5H^{11},C^6H^5$; Cl + 2PtcCl	Zot-methyla-ethyla-amyla-phenyla chlora bis platic chlora.

USUAL NAMES AND FORMULÆ OF THE SALTS OF THE VICE-AMMONS.

GROUP A. AMMONAMS = ZH^3M. Nos. 57 to 105.

57, Chlorhydrate of acetosamine. 58, Hydrated oxide of acetylium. 59, Chloride of alumina with ammonia = $3NH^3,Al^2Cl^3$. 60, Ditto, intermediate between 59 and 61. 61, Ditto = NH^3,Al^2Cl^3. See Gmelin's Handbook, iii. 320. 62, Isatate of silver, see Indigo, No. 7]. 63, Argento-chromate of ammonia = $NH^3AgO + NH^3,CrO^3$, *Gmelin*. 64, Indigo, 7]. 65, Hydrochlorate of butylamine = C^8NH^{11},HCl, *Gmelin*. 66, Cobaltic oxalate with ammonia = $12NH^3 + C^{12}Co^4O^{24} + 6$ aq., *Gmelin*. The occurrence of a basylic atom in company with ammonia is so uncommon that this analysis is probably incorrect. 67, Cupric oxalate with two atoms of ammonia = $2NH^3,C^4Cu^2O^8$, *Gmelin*. 68, Ditto with 1 atom ammonia = $NH^3,C^4Cu^2O^8$, *Gmelin*. 69, Ammonio-cupric oxalate = $C^4(NH^4,Cu)O^8$, *Gmelin*.[1] 70, Oxalate of ethylamine = $C^4(C^4H^8N)^2O^8$, *Gmelin*. 71, Hydrate of ethyl-ammonium = $O\begin{cases}H\\N(C^2H^5)H^3,\end{cases}$ *Gerhardt*. 72, Hydrochlorate of ethylamine, or chloride of ethylium = C^4H^7N,HCl or C^4H^8N,Cl, *Gmelin*. 73, Equivalent to 72. In this and similar cases it seems needless to repeat the names and formulæ merely to exchange Cl for Br. and I. 74, Chloro-aurate of ethylamine = $C^4H^7N, HCl + AuCl^3$ or $C^4H^8NCl,AuCl^3$, *Gmelin*. 75, Chloro-mercurate of ethylamine = $C^4H^7N,HCl + HgCl$, *Gmelin*. 76, Oxalate of methylamine = $C^4(C^2H^6N)^2O^8$, *Gmelin*. 77, Binoxalate of methylamine = $C^4(H,C^2H^6N)O^8$, *Gmelin*. 78, Chloride of methyl-ammonium = $Cl,N(CH^3)H^3$, *Gerhardt*. Hydrochlorate of methylamine = C^2H^5N,HCl, *Gmelin*. 79, and 80, Equivalent to 78. 81, Chloro-mercurate of methylamine = C^2H^5N, HCl, HgCl, *Gmelin.* 82, Chloro-aurate, equivalent to 81. 83, Chlorhydrate of naphtylamine = $C^{20}H^9N$,HCl, *Gerhardt.* 84 and 85, Equivalent to 83. 86, Oxalate of nickel with ammonia = $NH^3 + C^4Ni^2O^8$, *Gmelin.* 87, Oxalate of aniline = $C^2O^3,C^{12}H^7N + HO$, *Hofmann.* 88, Oxalate of bromaniline = $C^2O^3,C^{12}(H^6,Br)N,HO$, *Hofmann.* 89, Analogous to 88. 90 to 95, See Aniline, Nos. 12 to 17.[1] 96, Platinum-salt of the hydrochlorate of aniline. 97 to 100, See Aniline, Nos. 32 to 35.] 101, Isatate of potash, see Indigo, No. 7.][1] 102, Hydrochlorate of toluidine. 103, Platin-chloride of toluidine. 104, Aurochloride of toluidine. 105, Binoxalate of toluidine.

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[1] Nos. 67 and 69 contain water of crystallization, which is not expressed in the above formulæ. I shall, for the sake of brevity, omit water of crystallization in all cases where it does not affect the argument.

Group B. Ammonems = ZH^2M^2. Nos. 106 to 112.

106, Mercuric amido-chloride; infusible white precipitate = $Hg,NH^2 + HgCl$, *Kane* = $Hg^2N + HgCl + NH^4Cl$, *Rammelsberg* = $N\left(\begin{matrix}H^2\\Hg^2\end{matrix}\right)Cl$, *Watts.* 107, Iodide of dimethylammonium = $(H,H,C^2H^3,C^2H^3)NI$, *Hofmann.* 108, Iodide of ethyl-naphthylammonium. 109, See Aniline 22]. 110. Dibenzoylimide = $C^{28}H^{13}NO^2$, *Robson.* 111, Hydrobromate of ethylophenylamine. 112, Chloroplatinate of ethyl-toluidine.

Group C. Ammonims = ZHM^3. Nos. 113 to 117.

113, Hydrochlorate of triamylamine = $C^{30}H^{33}N$,HCl = $(C^{10}H^{11})^3N$,HCl, *Hofmann.* 114, Iodide of trimethylammonium = $(H,C^2H^3,C^2H^3,C^2H^3)NI$, *Hofmann.* 115, Bromide of diethylophenylammonium. 116, Iodide of methyl-toluenylammonium. 117, Platinum-salt of diethylamylammonium.

Group D. Ammonoms = ZM^4. Nos. 118 to 146.

118, Hydrated oxide of ammonium, or solution of ammonia in water = NH^3,HHO. 119, Chloride of ammonium, or hydrochlorate of ammonia; see page 197. 120, Oxalate of ammonia; see page 194. Normal salt = $C^4(2NH^4)O^8$, *Gmelin.* 121, Acid oxalate of ammonia = $C^4(H,NH^4)O^8$, *Gmelin.* 122, Hyperacid oxalate of ammonia = $C^4(H,NH^4)O^8,C^4H^2O^8$, *Gmelin.* 123, Isatic acid; see Indigo, 8.] 124, Iodide of tetramylammonium = $(C^{10}H^{11})^4NI$, *Hofmann.* 125, Hydrated oxide of tetramylammonium = $(C^{10}H^{11})^4NO,HO$, *Hofmann.* 126, Chloride of tetrethylammonium = $(C^4H^5)^4NCl$. 127, Iodide of tetrethylammonium = $(C^4H^5)^4NI$, *Hofmann.* 128, Hydrated oxide of tetrethylammonium = $(C^4H^5)^4NO,HO$, *Hofmann.* 129, Platinum-salt of tetrethylammonium = $(C^4H^5)^4NCl,PtCl^2$, *Hofmann.*[1] 130, Gold salt of tetrethylammonium = $(C^4H^5)^4NCl,AuCl^3$, *Hofmann.* 131, Iodide of tetramethylammonium = $(C^2H^3)^4NI$, *Hofmann.* 132, Hydrated oxide of tetramethylammonium $(C^2H^3)^4NO,HO$. 133, Platinum-salt of tetramethylammonium = $(C^2H^3)^4NCl, PtCl^2$, *Hofmann.* 134, Oxalate of tetramercurammonium = $C^4(NHg^4)^2O^8$, *Gerhardt.* 135, Iodide of triethylamylammonium $(C^4H^5)^3, C^{10}H^{11}, NI$. 136, Hydrated oxide of triethylamylammonium. 137, Platinum-salt of triethylamylammonium. 138, Hydrated oxide of triethylophenylammonium $C^{12}H^5(C^4H^5)^3NO,HO$, *Hofmann.* Gmelin assumes in this salt the presence of a compound which he calls trivinanilin = $C^{24}NH^{19} = C^{12}(C^4H^5)^3NH^2,H^2$. 139, Hydrated oxide of triethyl-toluenylammonium. 140, Chloroplatinate of triethyl-toluenylammonium. 141, Iodide of triethylomethylammonium = $C^2H^3(C^4H^5)^3NI$, *Hofmann.* 142, Iodide of methylodiethylamylammonium. 143, The platinum-salt of the chloride of methylodiethylamylammonium = $C^{20}H^{24}NCl,PtCl^2 = \left\{\begin{matrix} C^2\,H^3 \\ C^4\,H^5 \\ C^4\,H^5 \\ C^{10}H^{11} \end{matrix}\right\} NCl,PtCl^2$, *Hofmann.*

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[1] In the cases where compounds are fully explained in the sections headed Indigo, Aniline, &c., instead of repeating the explanations, I shall refer to them by numbers.

144, Iodide of methylethylamylophenylammonium = $\left\{\begin{matrix} C^2\,H^3 \\ C^4\,H^5 \\ C^{10}H^{11} \\ C^{12}H^5 \end{matrix}\right\} NI$, *Hofmann.* 145, The hydrated oxide of methylethylamylophenylammonium, *Hofmann.* 146, The platinum-salt of the last base

$$= C^{28}H^{24}NCl,PtCl^2 = \left\{\begin{matrix} C^2\,H^3 \\ C^4\,H^5 \\ C^{10}H^{11} \\ C^{12}H^5 \end{matrix}\right\} NCl,PtCl^2, \textit{Hofmann.}$$

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[1] Dr. Hofmann's formulæ of the ammonoms are generally written in the following style, which, in this instance, and in many other instances, I have compressed in the text to save room:

$$C^{16}H^{20}NCl,PtCl^2 = \left\{\begin{matrix} C^4H^5 \\ C^4H^5 \\ C^4H^5 \\ C^4H^5 \end{matrix}\right\} NCl,PtCl^2.$$

What advantage is gained by inflating the formula of an ammonium until it occupies four lines?

Investigation of the Compounds which are produced by the abstraction of Water from the Salts of Ammonia.

"The salts of oxide of ammonium, both neutral and acid, when subjected to the influence of heat, lose either two or four equivalents of water,[1] four classes of compounds being thus produced; neutral oxalate of oxide of ammonium by the loss of two equivalents of water becomes oxamide, while by the elimination of four equivalents of water cyanogen or oxalo-nitrile is formed. Binoxalate of ammonia, when losing two equivalents of water, is converted into oxamic acid. A compound arising from the binoxalate by the loss of four equivalents of water has not as yet been formed; this term, however, is found to be represented among the derivatives of the ammonia-salts of various other acids, *e. g.*, of camphoric and phthalic acids, camphorimide and phtalimide being bicamphorate and biphtalate of ammonia − 4 equivalents of water. We may thus distinguish as derived from the ammonia-salts by loss of water—

1. Amides.
2. Nitriles.
3. Amidogen-acids.
4. Imidogen-compounds. (Imides)."

—Hofmann, *Quarterly Journal of the Chemical Society* (1849), ii. 331.

I have copied Dr. Hofmann's classification, because it has been adopted by several chemists. I propose to examine the constitution of the compounds which constitute these four classes, and to show in what forms they respectively appear when viewed in the light of the Radical Theory.

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[1] In Hofmann's numbers two equivalents of water = HO + HO. This is only one equivalent on the radical theory = H,HO.

Amids produced by the abstraction of one atom of HHO from the Neutral Oxalates of Vice-Ammoniums.

147.	$ZH^2 ; CO$	Amida carbate.
148.	$ZH,C^6H^5 ; CO$	Phenylac carbate.
149.	$\left\{\begin{matrix} ZH,C^6H^5 ; CO \\ ZH^2 \quad ; CO \end{matrix}\right\}$	Phenylac carbate cum amida carbate.
150.	$ZH,C\,H^3 ; CO$	Methylac carbate.
151.	$ZH,C^2H^5 ; CO$	Ethylac carbate.
152.	$ZH,C^5H^{11} ; CO$	Amylac carbate.

USUAL NAMES OF THESE AMIDS.

147. Oxamide $= H^2NC^2O^2 = 2(H^2N)C^4O^4 = \left.\begin{matrix} C^4O^4 \\ H^2 \\ H^2 \end{matrix}\right\} N^2$, *Miller*. Oxamide, or diazoture of oxalyle and hydrogen $= C^2H^4N^2O^2 = N^2 \left\{\begin{matrix} C^2O^2 \\ H^2 \\ H^2 \end{matrix}\right.$ *Gerhardt*. $C^4Ad^2O^2,O^2$, *Gmelin*.

The rationale of the production of this compound is given at page 194. I have included oxamide in this section, for the sake of showing its relation to other amids.

DUMAS'S THEORY OF OXAMIDE.—"It has been supposed that oxamide might be represented by two binary elements—oxide of carbon and a particular azoture of hydrogen less hydrogenated than ammonia, and which has not yet been isolated. Oxamide under that form would be—

$$C^4O^2 + Az^2H^4.$$

Between these two components we have to find that which plays the negative part, and our choice is readily directed by the following consideration. We know that, in general, when a body decomposes water, its negative element takes up the hydrogen and its positive element the oxygen. Consequently, as oxamide decomposes water to pass to the state of oxalate of ammonia, we see that the azoture of hydrogen, which takes up the hydrogen, must be the negative element, and that the oxide of carbon which unites to the oxygen must act as the positive element in the compound."—Dumas, *Traité de Chimie appliquée aux Arts* (Liége, 1847), *partie Organique*, tome i. p. 64.

According to M. Dumas, amidogen, $= ZH^2$, acts in oxamide the same part that chlorine or cyanogen acts in neutral salts. It is the acid radical; while CO, or oxide of carbon, acts as the positive or metallic radical. The sole ground for this opinion is, that oxamide combines with water to produce oxalate of ammonia; and M. Dumas infers thence, that, since ZH^2 combines with H^2, ZH^2 must needs be an acid radical. That is his whole evidence, and very poor evidence it is. At the time of the discovery of oxamide, M. Dumas could not, of course, trace its true character as clearly as we can trace it now; but the assumptions that ZH^2 could be an acid radical, and that CO could be a basic radical, seem to me to be extravagant even for that period. They certainly are suggestions which would not have been listened to for an instant from a man who had been less successful in the world than M. Dumas.

148, Oxanilide; aniloxamide. See Aniline, No. 40]. 149, Oxanilamide; oxamid-aniloxamide. See Aniline, No. 41]. No. 148 is the amide of the vice-ammon oxalate, No. 87; and No. 149 is a double salt, composed of No. 147 and No. 148.

150, Dimethyl-oxamide, or diazoture of dimethyle and oxalyle. $C^4H^8N^2O^2 = N^2\left\{\begin{array}{c}C^2O^2\\(CH^3)^2\\H^2\end{array}\right.$

151, Diethyl-oxamide, or diazoture of diethyle and oxalyle. $C^8H^{12}N^2O^2 = N^2\left\{\begin{array}{c}C^2O^2\\(C^2H^5)^2\\H^2\end{array}\right.$

152, Diamyl-oxamide, or diazoture of diamyle and oxalyle. $C^{12}H^{24}N^2O^2 = N^2\left\{\begin{array}{c}C^2O^2\\(C^5H^{11})^2\\H^2\end{array}\right.$

The last three names and formulæ are Gerhardt's. In these formulæ everything is *doubled*, because Gerhardt chose to consider oxalic acid as bibasic. I have elsewhere shown the weakness of his arguments on that point (see page 177). Independently of the bibasic fallacy, the present examples are objectionable in another important particular: he formulates *oxidised salts* as *ammonias*—that is to say, as vice-ammonias, or substitutes for ZH^2,H^1. In doing this, he assumes that the acid radical of the salt with all the oxygen is *one of three forces which act equally upon the azotic atom*. Thus, $Z\left\{\begin{array}{l}CO\\CH^3\\H\end{array}\right.$. This assumption is of course gratuitous: it gives rise to complicated, and therefore troublesome, formulæ; and it conveys notions respecting the constitution, not only of ammonias, but of salts in general, which, in my opinion, are quite inaccurate, and which are totally at variance with the great principle of the radical theory, that all salts are compounds of two radicals. For these reasons I entirely reject Gerhardt's ammonia type. In simplicity and comprehensiveness it is much inferior to the plan which is provided by the radical theory.

Amids produced by the abstraction of one atom of HHO from the Neutral Salts that are formed by Normal Ammonium with Organic Acids.

		Proposed Names.	Usual Names.
153.	ZH^2,C^2H^3O	Amida acetylate . . .	Acetamide.
154.	ZH^2,C^2Cl^3O	Amida chlorinic-acetylate	Trichloracetamide.
155.	ZH^2,C^8H^7O	Amida anisylate . . .	Anisamide.
156.	ZH^2,C^7H^5O	Amida benzylate . . .	Benzamide.
157.	ZH^2,C^4H^7O	Amida butyrylate. . .	Butyramide.
158.	ZH^2,C^5H^7O	Amida camphorylate. .	Camphoramide.
159.	ZH^2,C^9H^7O	Amida cinnamylate . .	Cinnamide.
160.	$ZH^2,C^{10}H^{11}O$	Amida cumylate . . .	Cuminamide.
161.	$ZH^2,C^2H\ O$	Amida fumarylate . .	Fumaramide.
162.	ZH^2,C^8H^3O	Amida indylate . . .	Indigo blue.
163.	$ZH^2,C^8H^3O^2$	Amida indylete . . .	Isatine.
164.	$ZH^2,C^3H^5O^2$	Amida lactylete . . .	Lactamide.
165.	$ZH^2,C^3H^4O^3$	Amida mucylite . . .	Mucamide.
166.	$ZH^2,C^{10}H^7O$	Amida naphtylate. . .	Naphtylamide.
167.	$ZH^2,C^7H^{13}O$	Amida œnanthylate . .	Œnanthamide.
168.	ZH^2,C^3H^5O	Amida propionylate . .	Propionamide.
169.	ZH^2,C^5H^8O	Amida sebamylate . .	Sebamide.
170.	ZH^2,C^4H^6O	Amida suberylate . . .	Suberamide.
171.	ZH^2,C^2H^2O	Amida succinylate. . .	Succinamide.
172.	$ZH^2,C^2H^2O^2$	Amida tartrylete . . .	Tartramide.
173.	ZH^2,C^5H^9O	Amida valerylate . . .	Valeramide.

It is unnecessary to quote more than the usual names of the substances contained in this list. They all bear a similar relation to corresponding salts of ammonia. Thus, No. 153] = ZH^2,C^2H^3O amida acetylate, is commonly called acetamide, and has the formula $H^2N,C^4H^3O^2$. The addition of HHO to the new formula No. 153, converts it into $ZH^4,C^2H^3O^2$ = ammona acetylete, which, in the usual language of chemistry, is called acetate of ammonia, see page 198.

Practically, water is thus combined with these amids when they are boiled with diluted acids and alkalies.

Many of these salts have very complicated formulæ commonly given to them; but it does not appear that any advantage results from that practice. Gmelin's formula for mucamide = No. 165, amida mucylite, given above as $ZH^2,C^3H^4O^3$ is—

$$C^{12}N^2H^{12}O^{12} = C^{12}Ad^2H^8O^{10},O^2.$$

Gerhardt's formula for lactamide, = No. 164, amida lactylete = $ZH^2,C^3H^5O^2$ is—

$$N^2\left\{\begin{array}{c}(C^6H^5O^2)^2\\ H^2\\ H^2\end{array}\right.$$

These double quantities of atoms are given, because these chemists act upon the notion that certain acids are bibasic, or that the salts ought to be made equivalent to gases that have an atomic measure of four volumes, or because some other theory prescribes the duplication. The theory which I am advocating assumes all radicals to be equivalent to one volume of hydrogen, which, as a general rule, makes their salts equal to two volumes of vapour, and the practice which I pursue is that of cutting down the formulæ of all salts into accordance with this one simple idea.

There are several methods of producing these amids; such as, the action of ammonia on the anhydrides; the action of ammonia or carbonate of ammonia on the oxychlorides of organic acid radicals; and the action of ammonia on compound ethers.

They are neutral salts; namely, they are neutral to test-papers; they do not combine with acids; they are crystallizable.

M. Gerhardt says that " sometimes they behave like acids in regard to certain oxides; thus, benzamide forms a salt with mercury:

$$2N\left\{\begin{array}{c}C^7H^5O\\ H\\ H\end{array}\right. \quad + \quad O\left\{\begin{array}{c}Hg\\ Hg\end{array}\right. \quad = \quad 2N\left\{\begin{array}{c}C^7H^5O\\ Hg\\ H\end{array}\right. \quad + \quad O\begin{array}{c}H\\ H\end{array}.$$

Benzamide. Mercury benzamide."

Traité de Chimie Organique, iv. 761.

This transformation would be represented in my notation thus:

$$\left.\begin{array}{l}ZH^2,C^7H^5O\\ ZH^2,C^7H^5O\end{array}\right\} + HgcHgcO = \left\{\begin{array}{l}ZHHgc,C^7H^5O\\ ZHHgc,C^7H^5O\end{array}\right\} + HHO$$

This process is simply the conversion of amid into mericac by the replacement of H^1 by Hgc^1 in each atom of the salt.

Voit gives the ammonia formula to the compound that is commonly called binitrobenzamide, thus:

$$N\left\{\begin{array}{c}C^{14}H^3(NO^4)^2O^2\\ H\\ H\end{array}\right.$$

But this salt is evidently a compound of the same order as No. 156 in the above Table:

No. 156.] $ZH^2,C^7H^5\ O$ = Benzamide.
$ZH^2,C^7H^3Z^2O^5$ = Binitrobenzamide.

In this example O^4 extra goes into the salt because Z^2 goes into the radical instead of H^2. See page 133.

I might add other examples of this kind, but they could only prove the facts that have been detailed in the general notice of the properties of vice-radicals. See page 132.

Amids produced by the abstraction of one atom of HHO, from the Neutral Salts that are formed by Ammonams with Organic Acids.

174.	$ZH,C^4H^7; C^2H^3O$	Butyrylac acetylate.
175.	$ZH,C^2H^5; C^2H^3O$	Ethylac acetylate.
176.	$ZH,C^6H^5; C^2H^3O$	Phenylac acetylate.
177.	$ZH,C^6H^5; C^8H^7O^2$	Phenylac anisylete.
178.	$ZH,C^7H^5; C^7H^5O$	Benzylac benzylate.
179.	$ZH,Hgc; C^7H^5O$	Mericac benzylate.
180.	$ZH,C^6H^5; C^7H^5O$	Phenylac benzylate.
181.	$ZH,Hgc; C^4H^7O$	Mericac butyrylate.
182.	$ZH,C^6H^5; C^4H^7O$	Phenylac butyrylate.
183.	$ZH,C^6H^5; C^9H^7O$	Phenylac cinnamylate.
184.	$ZH,C^6H^5; C^{10}H^{11}O$	Phenylac cumylate.
185.	$ZH,C^2H^5; C\ H\ O$	Ethylac formylate.
186.	$ZH,C^6H^5; C\ H\ O$	Phenylac formylate.
187.	$ZH,Zn; C^2H^3O^2$	Zincac glycollylete.
188.	$ZH,C^6H^5; C^4H^6O$	Phenylac suberylate.
189.	$ZH,C^6H^5; C^2H^2O$	Phenylac succinylate.
190.	$ZH,C^6H^5; C^5H^9O$	Phenylac valerylate.

Each of these salts of an amid may be considered to be convertible by combination with HHO into the corresponding neutral salt of an ammonam. Thus, the first on the list, No. 174] $ZH,C^4H^7; C^2H^3O$ = butyrylac acetylate, if combined with HHO, would become $ZH^3,C^4H^7; C^2H^3O^2$, namely, butyrylam acetylete, or the acetate of an ammonium containing one atom of butyryl. But this change cannot always be effected experimentally, for when these amids are boiled with mineral alkalies, they suffer decomposition, the acid radical forming a salt with the alkali, and the amid being separated as a hydride or an ammonia. But though the corresponding salts of ammonams and amides cannot always be produced, it is important to bear in mind the existence of these relations.

USUAL NAMES AND FORMULÆ.

174, Butyric acetylamide $= \left.\begin{matrix} C^8H^7O^2 \\ C^4H^3 \\ H \end{matrix}\right\} N.$ *Miller*.

This formula is in accordance with Gerhardt's ammonia type, and is therefore subject to the objections which I have urged at page 210.

175, Acetoethylide.

175, Ethyl-acetamide, or Azoture of ethyle, acetyle, and hydrogen. $C^4H^9NO = N\begin{cases} C^2H^5 \\ C^2H^3O \\ H \end{cases}$

176, Phenyl-acetamide, Acetanilide, or Azoture of phenyle, acetyle, and hydrogen. $C^8H^9NO = N\begin{cases} C^6H^5 \\ C^2H^3O \\ H \end{cases}$

The last two formulæ and sets of names are Gerhardt's, written according to his type ammonia. All the salts from Nos. 175 to 184 are subject to the same treatment, but I think it useless to crowd this Essay with more than specimens of these digitated formulæ and their duplicate or triplicate names. It will suffice if the reader understands the difference between Gerhardt's system, and the system now under consideration. According to the radical theory, No. 176 is a direct binary compound between phenylac = ZH,C^6H^5 and acetylate = C^4H^3O, whereas, according to Gerhardt, it is a compound of N acting with tripartite force upon C^6H^5, and C^2H^3O, and H. It is the azoture of phenyl, of acetyle, *and* of hydrogen. From these views I dissent entirely. 177, Anisanilide; phenyl-anisamide. 178, Imabenzile. 179, Benzamidate of mercury, *Gerhardt;* hydrargo-benzamide, *Miller*. 180, Benzanilide; anilobenzamide. See No. 223. 181, Mercury-salt of butyramide. 182, Phenyl-butyramide; butyranilide. 183, Cinnanilide; anilo-cinnamide; phenyl-cinnamide. 184, Cumanilide; anilocuminamide. 185, Ethylformiamide. 186, Phenyl-formiamide; formanilide; aniloformamide; azoture of phenyle, of formyle, and of hydrogen. 187, Combination of sugar of gelatine and zinc = $2N(C^4H^3O^2,Zn,H)$. 188, Suberanilide; anilosuberamide; diphenyl-suberamide, or diazoture of diphenyle and of suberyle, *Gerhardt*. 189, Succinanilide; anilosuccinamide, *Hofmann;* diphenyl-succinamide, or diazoture of diphenyle, and of oxalyle, *Gerhardt*. 190. Phenyl-valeramide; valeranilide, or azoture of phenyle, of valeryle, and of hydrogen.

Non-oxidised Salts of Amids.

191.	$ZH,C^7H^5; Cl$ . .	Benzylac chlora.
192.	$ZH,K; C^6H^5$ . .	Potassac phenyla.
193.	$ZH,C^6H^5; Cy$ . .	Phenylac cyana.
194.	$Z,C^2H^5,C^6H^5; Cl$.	Ethylic-phenylac chlora.
195.	$Z,C^2H^5,C^2H^5; C^6H^4Cl$	Ethylec chloric-phenyla.
196.	$ZH,C^6H^3Cl^2; Cl$.	Chlorenic-phenylac chlora.
197.	$ZH,C^6H^3Br^2; Cl$.	Bromenic-phenylac chlora.
198.	$ZH,C^6H^3Br^2; Br$.	Bromenic-phenylac broma.

USUAL NAMES AND FORMULÆ.

191, Chloride of benzamidyle = Cl,C^7H^6N, *Gerhardt*. When heated, it produces hydrochloric acid and cyanide of phenyle $ZH,C^7H^5; Cl = HCl + C^6H^5,CN$. 192, see Aniline, No. 11]. 193, see Aniline, No. 62].

194, Ethyl-chloraniline $= C^{16}H^{10}ClN = C^{12}\left\{\begin{matrix}H^3\\ Cl\\ C^4H^5\end{matrix}\right\}N. = \left.\begin{matrix}H\\ H\\ C^{12}\begin{pmatrix}H^4\\ Cl\end{pmatrix}\end{matrix}\right\}N.$ *Hofmann.*

195, Biethyl-chloraniline $= C^{20}H^{14}ClN = C^{12}\left\{\begin{matrix}H^4\\ Cl\\ 2C^4H^5\end{matrix}\right\}N. = \left.\begin{matrix}C^4H^5\\ C^4H^5\\ C^{12}\begin{pmatrix}H^4\\ Cl\end{pmatrix}\end{matrix}\right\}N.$ *Hofmann.*

196, 197, 198; see Aniline, Nos. 9], 10], and 8].

Examples of the Combination of Ammons and Amids with one another.

199.	$ZH^3,C^7H^7 + ZH,C^7H^7$ . . .	Toluenylam toluenylac.
200.	$ZH^2(C^7H^5)^2 + ZH,C^7H^5$ . . .	Benzylem benzylac.
201.	$ZH^2(C^9H^7)^2 + ZH,C^9H^7$ . . .	Cinnamylem cinnamylac.
202.	$Z(CH^3)^2(C^2H^3)^2 + ZCH^3,C^2H^3$.	Methylenic-acetylem cum methylic-acetylac.
203.	$ZH^2 + ZH,C^{10}H^7$	Amida naphtylac.
204.	$ZH^2 + ZH,C^6H^5$	Amida phenylac.

USUAL NAMES AND FORMULÆ.

199, Lutidine, a compound isomeric with toluidine, No. 22; that is to say—

No. 22 two atoms $= \left\{\begin{matrix}ZH,C^7H^7; H\\ ZH,C^7H^7; H\end{matrix}\right\} = \left\{\begin{matrix}ZH^3,C^7H^7\\ ZH\ ,C^7H^7\end{matrix}\right\} =$ No. 199 one atom.

Two atoms of toluenylac hydra = one atom of toluenylam toluenylac. This accounts for the isomerism of these two salts, and supplies a hint as to the probable explanation of other cases of isomerism. 200, Hydrobenzamide = $C^{21}H^{18}N^2 = N^2\left\{\begin{array}{c}(C^7H^5)^3\\ H^3\end{array}\right.$, *Gerhardt.* $C^{42}H^{18}N^2$, *Miller.* 201, Cumhydramide = $C^{27}H^{24}N^2 = N^2\left\{\begin{array}{c}(C^9H^7)^3\\ H^3\end{array}\right.$, *Gerhardt.* $C^{54}H^{24}N^2$, *Miller.*

202, "Acetonine, or Acetonia, a new base = $C^{18}H^{18}N^2$. Hydrochlorate of acetonia forms with bichloride of platinum, an orange-yellow, crystalline double salt, $(C^{18}H^{18}N^2,HCl,PtCl^2)$. The binoxalate $(HO, C^{18}H^{18}N^2,HO\,;\,C^4O^6 + 2Aq)$ is soluble in alcohol, and crystallises readily from this soluble."—*Miller*, narrating the researches of Stædeler, *Elements of Chemistry*, Part iii, p. 312. I do not believe in the existence of this assumed "new base." Acetone itself contains acetyl and methyl, see page 77. Acetonia is composed of an ammon and an amid, including the same radicals; and the platinum-salt and the binoxalate can be explained (see Nos. 205, 206), without resorting to the expedient of creating a hypothetical "new base" to meet the special circumstances, an expedient to which organic chemists resort with a too-ready facility. When compound salts can be clearly explained by means of well-known existing radicals, what is the use of making imaginary bases? In the present case, three atoms of methyl, three atoms of acetyl, and two atoms of azote, are rolled up into a giant base and called acetonia. This method of practising chemical synthesis is becoming really alarming.

203, Azonaphtylamine; or seminaphtalidam = $C^{20}H^{10}N^2$, *Gerhardt.* Seminaphtalidine, or naphtidine = $C^{10}H^5N$, *Zinin.* $= C^{20}H^6(H^2N)^2$, *Hofmann.* 204, Semaniline = C^6H^4N, *Zinin.* $= C^{12}H^4(H^2N)^2$, *Hofmann.* When hydrated acids act upon the double amids, such as are represented by 203 and 204, they produce double salts which contain both an amid and an ammon; of which, Nos. 207 and 208 are examples:—

$$205.\ \left\{\begin{array}{r}Z(C\,H^3)^3Ptc\,;\ Cl\\ Z(C^2H^3)^3Ptc\,;\ Cl\\ H\,;\ Cl\end{array}\right\} = \begin{array}{l}\text{Platic-methylim chlora cum}\\ \quad\text{platic-acetylim chlora cum}\\ \quad\text{hydra chlora.}\end{array}$$

$$206.\ \left\{\begin{array}{r}ZH(C\,H^3)^3;\ CO^2\\ ZH(C^2H^3)^3;\ CO^2\\ Aq^1\end{array}\right\} = \begin{array}{l}\text{Methylim carbete cum ace-}\\ \quad\text{tylim carbete aquate.}\end{array}$$

$$207\ \left\{\begin{array}{l}ZH^3,C^{10}H^7;\ Cl\\ ZH^2\qquad\quad;\ Cl\end{array}\right\} = \text{Naphtylam chlora cum amida chlora.}$$

$$208\ \left\{\begin{array}{l}ZH^3,C^{10}H^7;\ SO^2\\ ZH^2\qquad\quad;\ SO^2\end{array}\right\} = \text{Naphtylam sulphete cum amida sulphete.}$$

No. 207 is commonly called the bichlorhydrate of azonaphtylamine, and No. 208 is the bisulphate of the same base. The hydrogen of the acids is, in each case, merely sufficient to convert one of the amids into an ammon; so that one amid remains still in the compound salt. It is possible that the last two salts may require the following formulæ:—

$$207,\ ZH,\ C^{10}H^{7};\ Cl\ \ + ZH^{4},\ \ Cl$$
$$208,\ ZH,\ C^{10}H^{7};\ SO^{2} + ZH^{4};\ SO^{2}$$

The compounds 203 and 204 do not form salts by combining with a single equivalent of H Cl or H SO^2.

Nitriles.

209.	CN	Cyana	[= Cyanogen].
210.	H,CN	Hydra cyana	[= Hydrocyanic acid].
211.	CH^3,CN	Methyla cyana	[= Cyanide of Methyl].

When oxalate of ammonia = ZH^4, CO^2 is deprived of two atoms of HHO, it is reduced to the condition which is shown in the following equation:—

$$\underset{\text{Oxalate of ammonia.}}{ZHHHH;\ \ COO} - \underset{\text{Water.}}{(HHO + HHO)} = \underset{\text{Residues.}}{Z + C.}$$

All that is left of the salt is the acid radical C, and the zotic atom which was the prime agent of the positive radical. These two atoms combine together and produce cyanogen, which is usually marked CN or Cy. This compound is not a salt composed of two radicals, but a single acid radical, energetic in its chemical powers, yet having the saturating capacity of only one atom. This fact is worthy of particular notice, because azote and carbon have each, separately, the saturating capacity of one radical, though, when combined, they have together only the saturating capacity of one radical. Thus azote, which, in positive radicals, paralyses the saturating capacities of the two or four radicals with which it produces amids and ammons, has its own saturating capacity paralysed when it enters into a negative radical which contains carbon. Even when two or three atoms of azote enter into a negative radical in the presence of carbon, they all lose their saturating capacity, that of the carbon radical alone remaining active.

See the account of the zotic radicals at page 132.

When formiate of ammonia = ZH^4, CHO^2, is deprived of two atoms of HHO, the result is as follows:—

$$\underset{\text{Formiate of ammonia.}}{ZHHHH;\ CHOO} - \underset{\text{Water.}}{(HHO + HHO)} = \underset{\text{Residues.}}{Z + CH.}$$

These residues are nitrogen and formyl.

When acetate of ammonia = $ZH^4,C^2H^3O^2$, is deprived of two atoms of HHO, the result is this :

$$\underset{\text{Acetate of ammonia.}}{ZHHHH\,;\ C^2H^3OO} - \underset{\text{Water.}}{(HHO + HHO)} = \underset{\text{Residues.}}{Z + C^2H^3.}$$

These residues are nitrogen and acetyl.

In both these cases the nitrogen combines with the other residue, and in all similar cases, when the neutral ammonia-salt of an organic acid is deprived of the hydrogen of its ammonium, and of all its oxygen, the residual nitrogen combines with the residual acid radical, and produces the compounds which are called NITRILES.

In an early part of this Essay, in treating of the reduction of acid radicals to basic radicals, I have shown that if you can, by any process, deprive an acid radical belonging to the vinyl series, of one atom of carbon, you reduce it at once to a basic radical. See page 75. Now it appears to me that, in the preparation of the nitriles, this reduction of an acid radical to a basic radical takes place in every instance. It is *à priori* improbable that the acid radical Z should combine with the acid radicals CH and C^2H^3, both of which are energetic acid radicals, if the acid power of the whole of them is supposed to be persistent; but if Z is supposed to abstract C from each of the hydrocarbons, the two pair of residues then become

$$\underset{=\text{ Hydrocyanic acid}}{H + CN} \qquad \text{and} \qquad \underset{=\text{ cyanide of methyl.}}{CH^3 + CN.}$$

That is to say, the two acid radicals Z + CH, become one basic radical (hydrogen) and one acid radical (cyanogen), and these combine together to produce a salt, the hydrocyanic acid. So, in the second example, the two acid radicals $Z + C^2H^3$ produce the strongly positive radical methyl CH^3 and the strongly negative radical cyanogen CN, and these combine to form the salt called cyanide of methyl = CH^3,CN. The evidence which I have given to prove the possibility of this reduction of acid radicals to basic radicals by the removal of an atom of carbon, is so convincing, that no man can doubt the fact; and when we couple with this certainty, the fact that the products of the three processes which I have supposed to yield the substances called oxalo-nitrile, formo-nitrile, and aceto-nitrile, actually yield cyanogen, hydrocyanic acid, and cyanide of methyl, we have reasons that are almost demonstrations to induce us to believe that in all these instances the nitrogen and the carbon combine to form cyanogen, and that this cyanogen produces a cyanide with the positive radical which is formed by the *residue* of the decomposed acid radical.

I have referred expressly to those ammonia-salts that are produced by the organic acids that belong to the vinyl series, page 79; but the formation of the so-called nitriles is not confined to radicals of that particular series; for the benzoate of ammonia yields cyanide of phenyl, and cuminate of ammonia yields cyanide of cumenyl, the benzoic radical being reduced to phenyl, that is to say = C^7H^5 to C^6H^5, and the cumyl radical to cumenyl = $C^{10}H^{11}$ to C^9H^{11}, by the abstraction, in each case, of C^1 to form cyanogen with the azotic residue of the destroyed ammonium.

According to this theory, azote, in the presence of sufficient radicals, exercises its prerogative of producing amidogens and ammoniums, which then form salts with oxidised carbon, with negative hydrocarbons, or with any other acid radicals, oxidised or not oxidised, which are placed within its reach. But neither amidogens nor ammoniums are produced in the absence of negative radicals with which they can form salts.

When the radicals necessary to the existence of ammonium-salts are *half* withdrawn from them, the salts are reduced to amides or amidogen-salts. When they are *all* withdrawn, the salts are destroyed and the azote is set free. When this happens in the presence of carbon, the free azote combines with the carbon to form cyanogen. When it happens in the presence of a negative hydrocarbon, it splits that negative hydrocarbon into C^1 and a positive hydrocarbon, and produces therewith a neutral cyanide.

This theory is quite consistent with well-ascertained facts respecting the formation of cyanogen, and the importance of the subject warrants my citing a few particulars. 1]. When a mixture of carbonate of potash and pure sugar-charcoal is heated red hot in a porcelain tube, and common atmospheric air is passed through the tube, cyanide of potassium is produced. 2]. Many vapours that contain carbon, if mixed with vapours that contain azote, and passed through a red-hot tube, produce cyanogen. 3]. When ammonia gas is passed over charcoal strongly ignited in a porcelain tube, cyanide of ammonium and marsh gas are produced, thus:—

$$\left.\begin{array}{l} 4(ZH^2H) \\ 3C \end{array}\right\} = \left\{\begin{array}{l} 2(ZH^4,CN) \\ CH^3,H. \end{array}\right.$$

4]. Ammonia gas and carbonic oxide, passed through a red-hot tube, produce cyanide of ammonium and water; thus:—

$$ZH^2H,ZH^2H + CO = ZH^4,CN + HHO.$$

5]. When refuse animal matter, such as horns, hides, hoofs, &c., are heated red-hot in a close vessel with carbonate of potash and iron filings, the triple cyanide of iron and potassium = K^2FeCy^3, is produced. The phenomena that occur in this last example are complicated; but the final product alone is what we have to consider. It is evident that the ammoniacal compounds which these animal substances contain in large quantities with an excess of carbon are converted during the operation into cyanogen, the hydrogen and oxygen of the compounds being wholly disengaged, because the cyanogen combines with the potassium and iron, without the intervention of oxygen.

RECONVERSION OF THE NITROGEN OF CYANOGEN INTO THE AMMONIACAL CONDITION.

It is not only possible to remove nitrogen from amidogen or ammonium into cyanogen; but to perform the reverse operation of forcing the nitrogen of a cyanide to transmigrate into the ammoniacal condition. Of course, these transmigrations result from the fact, that nitrogen can act either negatively or positively, according to the pressure of the positive or negative forces that are made to control it, and that it changes *its* condition with every sufficient change in those controlling forces.

Examples:

$$1.\ \left\{\begin{matrix} H,CN + H,Cl \\ H,HO + H,HO \end{matrix}\right\} = \left\{\begin{matrix} ZH^4,Cl \\ H,CHO^2 \end{matrix}\right.$$

One atom of hydrocyanic acid, one atom of hydrochloric acid, and two atoms of water produce, one atom of chloride of ammonium, and one atom of hydrated formic acid.

$$2.\ \left\{\begin{matrix} K,CN + H,Cl + H,Cl \\ H,HO + H,HO \end{matrix}\right\} = \left\{\begin{matrix} ZH^4,Cl \\ K,Cl \\ H,CHO^2. \end{matrix}\right.$$

One atom of cyanide of potassium, two atoms of hydrochloric acid, and two atoms of water produce, one atom each of chloride of ammonium, chloride of potassium, and hydrated formic acid.

$$3.\ \left\{\begin{matrix} K,CN \\ H,HO + H,HO \end{matrix}\right\} = \left\{\begin{matrix} K,CHO^2 \\ ZH^2,H. \end{matrix}\right.$$

One atom of cyanide of potassium boiled in a close vessel with two atoms of water produces one atom of ammonia and one atom of formiate of potash.

$$4.\ \left\{\begin{matrix} K,CNO + H,HO \\ H,SO^4 + H,SO^4 \end{matrix}\right\} = \left\{\begin{matrix} ZH^4,SO^4 \\ K,SO^4 \\ CO^2. \end{matrix}\right.$$

One atom of cyanate of potash, one atom of water, and two atoms of hydrated sulphuric acid, produce one atom each of sulphate of ammonia, sulphate of potash, and free carbonic acid.

$$5.\ \left\{\begin{matrix} ZH^4,CNO \\ H,HO + H,HO \end{matrix}\right\} = ZH^4,ZH^4,CO^3.$$

One atom of urea (cyanate of ammonia) heated in a sealed tube with two atoms of water, produces one atom of carbonate of ammonia.

If we examine the nature and consequences of these various reactions, and then ask ourselves the question, whether the nitriles consist of nitrogen combined directly with unchanged negative radicals, $Z + CH$, $Z + C^2H^3$, $Z + C^3H^5$, $Z + C^4H^7$, $Z + C^5H^9$, $Z + C^7H^5$, &c., or whether they are cyanides of the corresponding positive radicals?—we can scarcely come to any other conclusion than that which has been drawn above, namely, that the NITRILES are in *all* cases to be considered as CYANIDES, and that *nitriles proper*, or compounds of nitrogen with negative radicals, do not exist.

[Consult the investigation into the constitution of the compound commonly called anilocyanic acid, Article Aniline, No. 95.]

Carbamide.

212. ZH^4 ; CyO, Ammona cyanate = [carbamide or urea].
213. $ZH^2(C^6H^5)^2$; CyO, Phenylem cyanate = [carbanilide].
214. ZH^3,C^6H^5 ; CyO, Phenylam cyanate = [carbamide-carbanilide].

The following formulæ represent the neutral carbonate of ammonia:

Analytical formula.	Synoptical formula.
$ZH^4O + ZH^4O + CO$	ZH^4,ZH^4,CO^3.

If we imagine two atoms of HHO to be abstracted from this compound, the residue will be as follows:—

$$ZH^2 + ZH^2 + CO.$$

This formula represents CARBAMIDE.

If we ask ourselves the question, whether this formula *probably* represents the constitution of this residue, we must, before we make a reply, take into consideration the following particulars, which I have in the preceding pages almost demonstrated to be matters of fact.

1. One atom of Z can, with facility, hold either H^2 or H^4 in the form of a positive radical; but H^4 more effectually than H^2.

2. When Z is freed from H, in the presence of C, it combines with C, and produces cyanogen. [illegible]

3. If any positive radical is present, the resulting cyanogen combines with it to form a salt.

What is to prevent the occurrence of these reactions among the elements that constitute carbamide? I can see no counteracting force whatever, and I believe that, in the circumstances that are presented by the process above described, azote would infallibly fulfil its usual functions, and that the so-called carbamide, with the formula ZH^2,ZH^2,CO, would become ZH^4,CNO, or ammona cyanate, a compound which, in the usual language of chemists, is called cyanate of ammonia, or briefly UREA. I can find no sufficient reason to retain either the name carbamide or the formula upon which that name is based. The opinions of chemists are at present divided upon this subject; but I trust that the facts and contingencies which I have pointed out in this Essay respecting the properties of ammoniums, amidogens, and cyanogen compounds, and the demonstration of the circumstances which regulate the amazing power of transmigration possessed by the element azote, will bring them to agree in the propriety of my conclusions.

The arguments which bear upon the constitution of carbamide are precisely similar to those which must be used if I were to enter into a description respecting the constitution of the compounds which Dr. Hofmann has called carbanilide and carbamide-carbanilide. The former of these compounds is represented by No. 213, and the latter by No. 214. I refer the reader for a complete investigation of these two compounds to Aniline, No. 90].

The usual formula given to carbamide is H^2N,CO, *Hofmann;* but as the radical theory doubles the weight of the atoms of C and O, this formula requires to be changed to H^2N,H^2N,CO, to express the same percentage relations.

The constitution of "Urea" will be more fully discussed in a subsequent section.

Imidogen Compounds. Imides. Aniles.

According to Dr. Hofmann, the IMIDES are produced by the abstraction of four equivalents of water [that is, two equivalents on the radical theory] from an acid salt of ammonia. He tells us, that the imide resulting from the binoxalate of ammonia has not as yet been formed; but that we have representatives of the imidogen compounds among the derivatives of camphoric and phtalic acids. See page 208.

Let us first see, why the binoxalate of ammonia produces no imide:

p.221

$$\begin{array}{ccccc} \text{Binoxalate of Ammonia.} & & \text{Water.} & & \text{Residue.} \\ \left.\begin{array}{r} ZH^4;\ CO^2 \\ H;\ CO^2 \end{array}\right\} & - & (HHO,HHO) & = & \left\{\begin{array}{l} Z + C \\ H + CO^2. \end{array}\right. \end{array}$$

This residue produces hydrocyanic acid = H,CN, and carbonic acid = CO^2, which do not enter into combination; and this is the reason why oximide "has not *as yet* been formed," and why it never will be formed.

Decomposition of Bicamphorate of Ammonia.

$$\begin{array}{ccccc} \text{Bicamphorate of Ammonia.} & & \text{Water.} & & \text{Residue.} \\ \left.\begin{array}{r} ZH^4;\ C^5H^7O^2 \\ H;\ C^5H^7O^2 \end{array}\right\} & - & \left\{\begin{array}{c} HHO \\ HHO \end{array}\right\} & = & \left\{\begin{array}{l} Z + C^5H^7 \\ H + C^5H^7O^2. \end{array}\right. \end{array}$$

What becomes of this residue? According to Dr. Hofmann, it produces camphorimide, the formula of which is $HN,2C^{10}H^7O^2$. Correcting the atomic weights of C and O, this formula becomes $HN,2C^5H^7O$. The first part of this formula is Hofmann's "Imide" = HN.

I dissent from this theory entirely, and I consider that no such thing as an imide exists. Let us compare the residues of the two processes just referred to:

$$\text{First residue,}\left\{\begin{matrix} Z + C \\ H + CO^2 \end{matrix}\right. \qquad \text{Second residue,}\left\{\begin{matrix} Z + C^5H^7 \\ H + C^5H^7O^2 \end{matrix}\right.$$

If the three radicals $Z + C + H$ can combine together, what is to prevent the combination of the three radicals $Z + C^5H^7 + H$, which are placed in contact under precisely similar circumstances? The *reason* for the combination in the first case is the tendency of carbon and nitrogen to form cyanogen. The *reason* for the combination in the second case is the power of nitrogen in the presence of two free radicals and an oxidised negative radical to produce a salt of an amidogen. The result of the combination in the first case is an acid radical which takes up the basic hydrogen left free by the disengagement of carbonic acid. The result of the combination in the second case is a basic radical which combines with the camphoric acid left free by the abstraction of the hydrogen, and the final product is a neutral salt with a vice-amidogen base, thus:

$$ZH,C^5H^7;\ C^5H^7O^2 = \text{Camphorylac camphorylete.}$$

Decomposition of Biphtalate of Ammonia.

Precisely the same thing takes place when biphtalate of ammonia is decomposed.

$$\left.\begin{matrix} ZH^4;\ C^4H^2O^2 \\ H;\ C^4H^2O^2 \end{matrix}\right\} - \left\{\begin{matrix} HHO \\ HHO \end{matrix}\right\} = \left\{\begin{matrix} Z;\ C^4H^2 \\ H;\ C^4H^2O^2. \end{matrix}\right.$$

$$= ZH,C^4H^2;\ C^4H^2O^2 = \text{Phtalylac phtalylete.}$$

Dr. Hofmann's name and formula for this compound are

$$HN,2C^8H^2O^2 = \text{Phtalimide.}$$

It is needless to give more examples of the imides, for they would be repetitions of camphorimide, with the mere change of the acid radical. It will suffice to quote a few varieties of these salts in a Table. In all cases they are neutral salts, containing the full quantity of oxygen required by the acid radical, but having a vice-amidogen as basic radical. It may perhaps be urged that even my formulæ contain ZH, and that the salts may therefore contain imidogen; but since ZH must occur in every amidogen and ammonium, in which all the hydrogen has not been replaced, this argument proves nothing. There is no such thing as isolated imidogen, and a theoretical one is not required.

EXAMPLES OF IMIDES AND ANILES.

a). *Amidacs.* (*Imides.*)

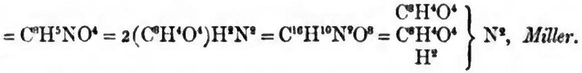
215.	ZH,C^7H^5;	$C^7H^5O^2$	Benzylac benzylete.
216.	ZH,Ba;	$C^7H^5O^2$	Barytac benzylete.
217.	ZH,Na;	$C^7H^5O^2$	Natrac benzylete.
218.	ZH,C^5H^7;	$C^5H^7O^2$	Camphorylac camphorylete.
219.	ZH,C^2H;	$C^2H\,O^2$	Fumarylac fumarylete.
220.	ZH,C^4H^2;	$C^4H^2O^2$	Phtalylac phtalylete.
221.	ZH,C^2H^2;	$C^2H^2O^2$	Succinylac succinylete.

b). *Amidecs.* (*Aniles*, etc.)

222.	Z,C^2H^5,C^2H^3;	$C^2H^3O^2$	Ethylic-acetylac acetylete.
223.	Z,C^7H^5,C^6H^5;	$C^7H^5O^2$	Benzylic-phenylac benzylete.
224.	Z,C^5H^7,C^6H^5;	$C^5H^7O^2$	Camphorylic-phenylac camphorylete.
225.	Z,C^4H^2,C^6H^5;	$C^4H^2O^2$	Phtalylic-phenylac phtalylete.
226.	Z,C^2H^2,C^6H^5;	$C^2H^2O^2$	Succinylic-phenylac succinylete.

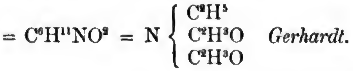
SYNONYMES AND USUAL FORMULÆ.

215. Benzimide = $HN,2C^{14}H^5O^2$, *Hofmann.* **216**, Amidobenzoate of barytes = $BaOC^{14}H^4NH^2O^3 = C^{14}H^4Ba(NH^2)O^4$, *Voit.* **217**, Amidobenzoate of soda = $C^{14}H^4Na(NH^2)O^4$, *Voit.* These two salts are liable to another interpretation. See Tribasic cyanates. See also No. 474 in this series. Voit's Memoir may be seen in the *Quarterly Journal Chem. Soc.* ix., 268. **218.** Camphorimide = $HN,\ 2C^{10}H^7O^2$, *Hofmann.* **219.** Fumarimide = $C^8H^3NO^4$, *Gerhardt.* **220.** Phtalimide = $HN,\ 2C^8H^2O^2$, *Hofmann.* **221.** Succinimide, or bisuccinamide



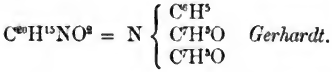
$$= C^8H^5NO^4 = 2(C^8H^4O^4)H^2N^2 = C^{16}H^{10}N^2O^8 = \left.\begin{matrix} C^8H^4O^4 \\ C^8H^4O^4 \\ H^2 \end{matrix}\right\} N^2, \textit{ Miller.}$$

222. Ethyl-diacetamide, or azoture of ethyle and of diacetyle



$$= C^6H^{11}NO^2 = N\left\{\begin{matrix} C^2H^5 \\ C^2H^3O \\ C^2H^3O \end{matrix}\right. \quad \textit{Gerhardt.}$$

223. Phenyl-dibenzamide, dibenzanilide, or azoture of phenyle and of dibenzoile



$$C^{20}H^{15}NO^2 = N\left\{\begin{matrix} C^6H^5 \\ C^7H^5O \\ C^7H^5O \end{matrix}\right. \quad \textit{Gerhardt.}$$

Compare Dibenzanilide, No. 223, and Benzanilide, No. 180, with the ammonium-salts to which they respectively correspond:—

$$\text{No. 223. } \left.\begin{matrix} ZC^7H^5,C^6H^5;\ C^7H^5O^2 \\ H^2;\quad H^2O^2 \end{matrix}\right\} = \left\{\begin{matrix} ZH^3,C^6H^5;\ C^7H^5O^2 \\ H;\ C^7H^5O^2 \end{matrix}\right.$$

$$\text{No. 180. } \left.\begin{matrix} ZH,C^6H^5;\ C^7H^5O \\ H;\quad H\ O \end{matrix}\right\} = ZH^3,C^6H^5;\ C^7H^5O^2$$

224. Camphoranile; anilocamphorimide $= C^{32}H^{19}NO^4 = C^{12}H^5N,2C^{10}H^7O^2$, *Hofmann*. Phenyl-camphorimide, or azoture of phenyle and of camphoryle

$$= N \left\{\begin{matrix} C^{10}H^{14}O^2 \\ C^6H^5. \end{matrix}\right. \quad \textit{Gerhardt.}$$

225. Phenyl-phtalimide, phtalanile, or azoture of phenyle and phtalyle

$$= C^{14}H^9NO^2 = N \left\{\begin{matrix} C^8H^4O^2 \\ C^6H^5 \end{matrix}\right. \quad \textit{Gerhardt.}$$

Phtalanile, or anilophtalimide $= C^{12}H^5N,2C^8H^2O^2$, *Hofmann*. **226.** Succinanile, or anilosuccinimide $= C^{20}H^9NO^4 = C^{12}H^5N,2C^4H^2O^2$, *Hofmann*. Phenyl-succinimide, or azoture of phenyle and of succinyle

$$= N \left\{\begin{matrix} C^4H^4O^2 \\ C^6H^5 \end{matrix}\right. \quad \textit{Gerhardt.}$$

The compounds No. 223 to 226 belong to the class which Dr. Hofmann calls "aniles." They are derived from the acid salts of phenylam:

$$\left.\begin{matrix} ZH^3,C^6H^5;\ C^7H^5O^2 \\ H;\ C^7H^5O^2 \end{matrix}\right\} - \left\{\begin{matrix} H^2O \\ H^2O \end{matrix}\right\} = \begin{matrix} ZC^7H^5,C^6H^5;\ C^7H^5O^2 \\ \text{No. 223.} \end{matrix}$$

The salt No. 222 shows that this series is not confined to aniline, but has a general character. The Anilidogen (C^6H^5N), which is commonly assumed to be present in the "aniles," is a phantom.

Amidogen Acids. Amidated Acids. Amided Acids.

The amidated acids are produced when one atom of HHO is abstracted from an acid salt of ammonia. Example:

$$\begin{matrix} \text{Binoxalate of Ammonia.} & \text{Water.} & \text{Residue.} \\ \left.\begin{matrix} ZH^4;\ CO^2 \\ H;\ CO^2 \end{matrix}\right\} & - \ HHO = & \left\{\begin{matrix} ZH^2;\ CO \\ H;\ CO^2 \end{matrix}\right. \end{matrix}$$

This residue is a double salt, consisting of an atom of normal hydrated oxalic acid and an atom of a salt containing amidogen as a base. This double salt is called oxamic acid. See page 195. The single atom of hydrogen is replaceable by a positive radical, and all the other elements of the salt pass into the new salt. We may apply a systematic name to oxamic acid either according to its analytical or its synoptical formula, thus:—

$ZH^2,CO+HCO^2$ = amida carbate cum hydra carbete.
$H,ZH^2;\ C^2O^3$ = hydra amida carbenite.

The latter is the briefest name, and it is sufficiently explicit. The following are some of the salts of this "acid":—

A. OXAMATES.

227.	$H;\ ZH^2;\ C^2O^3$ . . .	Hydra amida carbenite.
228.	$Am;\ ZH^2;\ C^2O^3$ . . .	Ammona amida carbenite.
229.	$Ba;\ ZH^2;\ C^2O^3$ . . .	Baryta amida carbenite.
230.	$Ag;\ ZH^2;\ C^2O^3$ . . .	Argenta amida carbenite.
231.	$CH^3;\ ZH^2;\ C^2O^3$ . . .	Methyla amida carbenite.
232.	$C^2H^5;\ ZH^2;\ C^2O^3$ . .	Ethyla amida carbenite.
233.	$C^2Cl^5;\ ZH^2_4;\ C^2O^3$ . .	Chlorunic-ethyla amida carbenite.
234.	$C^5H^{11};\ ZH^2;\ C^2O^3$ . .	Amyla amida carbenite.
235.	$CH^2Ca;\ ZH^2;\ C^2O^3$ . .	Calcic-methyla amida carbenite.

Analytical Formula; $ZH^2,\ CO + H^r,\ CO^2$.

USUAL NAMES.—227. Oxamic acid = $C^4NH^3O^6$. 228. Oxamate of ammonia. 229. Oxamate of barytes. 230. Oxamate of silver. 231. Oxamethylane; oxalformamester = $C^6NH^5O^6 = C^2H^3Ad,C^4O^6$, *Gmelin*. 232. Oxamethane; oxalvinamester; oxalovinate of ammonia = $C^8NH^7O^6 = C^4AdH^6,\ C^4O^6$, *Gmelin*. 233. Chloroxamethane; chloroxethamide = $C^8NH^2Cl^5O^6 = C^4AdCl^5,C^4O^6$, *Gmelin*. 234. Oxamylane = $C^{14}H^{13}NO^6$, *Gerhardt*. 235. Methyloxamate of lime = $C^4N\ (H,\ C^2H^3,Ca)\ O^6$, *Gmelin*.

At No. 231, there is a remarkable divergence in the ordinary nomenclature of these salts. Organic chemists first introduce us to "Oxamic acid," and then, the basic hydrogen of the "acid" being replaced by Am, Ba, Ag, &c., we obtain salts which we are desired to term oxamates. That course is quite proper if we admit the existence of oxamic acid. But no sooner does a positive hydrocarbon appear in the place of the basic radical, when, presto! the oxamate vanishes and we find that we are dealing with an amethane! "The amethanes formed by wood-spirit are called methylanes or formamethanes; these formed by common alcohol, ethylanes, vinamethanes, or simply amethanes; and those formed by fusel-oil, amylanes, or mylamethanes." *Gmelin*. And what is the use of all these trivial, non-systematic names? Why did not oxamate of methyl, of ethyl, and of amyl, answer the purpose? What good end is obtained by dividing the salts of oxamic acid—supposing we submit to have oxamic acid—into two battalions, and calling one of them oxamates and the other amethanes? The first false step in this course is that of applying the name "acid" to the double salt No.

227 = $ZH^2,CO+HCO^2$. That is an illogical commencement, and leads to the vague and confused notions according to which the other names are perpetrated.

B. Oxanilates.

236. $H;\ ZH,C^6H^5;\ C^2O^3$. . .	Hydra phenylac carbenite.
237. $Ba;\ ZH,C^6H^5;\ C^2O^3$ . .	Baryta phenylac carbenite.
238. $Ag;\ ZH,\ C^6H^5;\ C^2O^3$ . .	Argenta phenylac carbenite.
239. $Am;\ ZH,C^6H^5;\ C^2O^3$ . .	Ammona phenylac carbenite.
240. $\left\{\begin{matrix} Am;\ ZH,C^6H^5;\ C^2O^3 \\ H:\ ZH,C^6H^5;\ C^2O^3 \end{matrix}\right\}$	Ammona phenylac carbenite cum hydra phenylac carbenite.
241. $\left\{\begin{matrix} ZH^2,C^6H^5;\ ZH,C^6H^5;\ C^2O^3 \\ H;\ ZH,C^6H^5;\ C^2O^3 \end{matrix}\right\}$	Phenylam phenylac carbenite cum hydra phenylac carbenite.

Analytical formula of No. 236: $ZH,C^6H^5;\ CO + H^r,CO^2$

Synonymes:—236. Oxanilic acid; anilo-oxamic acid = H,C^2O^4; $C^{12}H^6N,C^2O^2 = C^{16}H^7NO^6 = HO.C^2O^3$; $C^{12}H^6N,C^2O^2 = HO.C^2\left\{\begin{matrix} O^2 \\ C^{12}H^7N \end{matrix}\right.$ C^2O^3. *Hofmann*. See Aniline, No. 50]. 237. See Aniline, 51]. 238 and 239 are analogous salts to No. 237. 240. Acid-oxanilate of ammonia = $NH^4O,C^2\left\{\begin{matrix} O^2 \\ C^{12}H^7N \end{matrix}\right. C^2O^3 + HO\,.\,C^2\left\{\begin{matrix} O^2 \\ C^{12}H^7N \end{matrix}\right. C^2O^3$. *Hofmann*. 241. See Aniline, 52].

The oxanilates differ from the oxamates by containing phenylac instead of amid. I see nothing to prevent the occurrence of similar salts with any other amidac, each salt being formed in agreement with the following general formula:

$$H^r;\ ZH,M^r;\ C^2O^3 = \text{hydra amidac carbenite};$$

in which formula M^r signifies a replaceable radical = C^mH^n.

C. Amidogen-acids with compound Radicals.

242. $H;\ ZH^2;\ (C^5H^7)^2O^3$. .	Hydra amida camphorylenite.
243. $H;\ ZH^2;\ (C^4H^2)^2O^3$. .	Hydra amida phtalylenite.
244. $H;\ ZH^2;\ (C^5H^8)^2O^3$. .	Hydra amida sebamylenite.
245. $H;\ ZH^2;\ (C^2H^2)^2O^3$. .	Hydra amida succinylenite.
246. $Ag;\ ZH^2;\ (C^2H^2)^2O^3$.	Argenta amida succinylenite.

Analytical formula of No. 242: $ZH^2,C^5H^7O + H^r,C^5H^7O^2$.

These salts differ from the oxamates 227 to 235, only by containing compound acid radicals instead of the simple carbon radical of the oxalic acid. Their derivation and structure are perfectly analogous to those of the oxamates.

Usual Names.—242. Hydrated camphoramic acid = $HO,H^2N,C^{20}H^{14}O^5$, *Miller*. 243. Phtalamic acid = $HO,H^2N,C^{16}H^4O^5$, *Miller*. 244. Sebamic acid = $C^{20}H^{19}NO^6$, *Gerhardt*. 245. Succinamic acid, or hydrate of succinylammonium $= O\left\{\begin{matrix}H\\ N(C^4H^4O^2)H^2,\end{matrix}\right.$ *Gerhardt.*

246. Succinamate of silver $= O\left\{\begin{matrix}Ag\\ N(C^4H^4O^2)H^2,\end{matrix}\right.$ *Gerhardt.*

D. ANILIDOGEN-ACIDS WITH COMPOUND RADICALS.

247. $H;\ ZH,C^6H^5;\ (C^5H^7)^2O^3$. Hydra phenylac camphorylenite.
248. $H;\ ZH,C^6H^5;\ (C^4H^2)^2O^3$. Hydra phenylac phtalylenite.
249. $H;\ ZH,C^6H^5;\ (C^4H^6)^2O^3$. Hydra phenylac suberylenite.
250. $H;\ ZH,C^6H^5;\ (C^4H^2)^2O^3$. Hydra phenylac succinylenite.

Analytical formula: $ZH,C^6H^5;\ C^5H^7O + H^r;\ C^5H^7O^2$.

These compounds are Dr. Hofmann's anilic or anilidogen acids. They differ from the salts of section C only in containing phenylac instead of normal amid. Hofmann's names and formulæ are as follow :—

247. Camphoranilic acid $= H,C^{10}H^7O^4;\ C^{12}H^6N,C^{10}H^7O^2$.
248. Phtalanilic acid . $= H,C^8H^2O^4;\ C^{12}H^6N,C^8H^2O^2$.
249. Suberanilic acid . $= H,C^8H^6O^4;\ C^{12}H^6N,C^8H^6O^2$.
250. Succinanilic acid . $= H,C^4H^2O^4;\ C^{12}H^6N,C^4H^2O^2$.

This concludes the investigation of the four classes of dehydrated compounds described by Hofmann at page 208.

Hydramides.

251. $\left\{\begin{matrix}ZH^2 & ;\ C^8H^7O\\ ZH,C^8H^7 & ;\ C^8H^7O^2\end{matrix}\right\}$ Anisylac amida anisylenite.

252. $\left\{\begin{matrix}ZH^2 & ;\ C^5H^3O\\ ZH,C^5H^3 & ;\ C^5H^3O^2\end{matrix}\right\}$ Furfurylac amida furfurylenite.

253. $\left\{\begin{matrix}ZH^2 & ;\ C^7H^5O\\ ZH,C^7H^2Cl^3 & ;\ C^7H^5O^2\end{matrix}\right\}$ Chlorinic-benzylac amida benzylenite.

254. $\left\{\begin{matrix}ZH^2 & ;\ C^7H^5O\\ ZH,C^7H^2Br^3 & ;\ C^7H^5O^2\end{matrix}\right\}$ Brominic-benzylac amida benzylenite.

GERHARDT'S NAMES AND FORMULÆ.

251. Anishydramide $= C^{24}H^{24}N^2O^3 = N^2\left\{\begin{matrix}(C^8H^7O)^3\\ H^3\end{matrix}\right.$

252. Furfuramide $= C^{15}H^{12}N^2O^3 = N^2\left\{\begin{matrix}(C^5H^3O)^3\\ H^3\end{matrix}\right.$

253. Chlorosamide $= C^{21}H^{15}Cl^3N^2O^3 = N^2\left\{\begin{matrix}(C^7H^4(Cl)O)^3\\ H^3\end{matrix}\right.$

254. Bromosamide $= C^{21}H^{15}Br^3N^2O^3 = N^2\left\{\begin{matrix}(C^7H^4(Br)O)^3\\ H^3\end{matrix}\right.$

These hydramides are double salts, each of them containing an "amide" similar to No. 153, with an "imide" similar to No. 215. Only a few of them have been discovered, but there can be no doubt that many more will be found, now that their nature is understood.

Sulphates with Inorganic Vice-Ammons.

GROUP A.

255. ZH^4 ; SO^2 Ammona sulphete.
256. ZH^3Zn ; SO^2 Zincam sulphete.
257. ZH^3Cuc ; SO^2 Cupricam sulphete.
258. ZH^3Ag ; SO^2 Argentam sulphete.
259. ZH^3Pt ; SO^2 Platousam sulphete.

USUAL NAMES AND FORMULÆ.—255, Sulphate of ammonia = NH^4O,SO^3. 256 to 259, These salts are sulphates containing the vice-ammoniums to which I have given the name of ammonam. See page 193. Namely, they are sulphates of normal ammonium in which H^1 has been replaced by M^1. They are commonly considered as sulphates of metallic protoxides combined with one atom of ammonia. For an account of No. 259, see Platinum, No. 43.

GROUP B.

260. $ZH^3Mn; SO^2 + ZH^2,H$ Mangam sulphete cum amida hydra.
261. $ZH^3Zn; SO^2 + ZH^2,H$ Zincam sulphete cum amida hydra.
262. $ZH^3Cd; SO^2 + (ZH^2,H)^2$ Cadmam sulphete bis amida hydra.
263. $ZH^3Co; SO^2 + ZH^2,H$ Cobaltousam sulphete cum amida hydra.
264. $ZH^3Ni; SO^2 + ZH^2,H$ Niccolousam sulphete cum amida hydra.
265. $ZH^3Ag; SO^2 + ZH^2,H$ Argentam sulphete cum amida hydra.

These compounds are examples of the ammoniated salts, of which I have given an account at page 198. It seems needless to quote their ordinary names, as the formulæ render them obvious. No. 260 is sulphate of manganese with two atoms of ammonia $= MnO,SO^3 + 2NH^3$. The names of the others correspond to this example.

GROUP C.

266. $ZH^4; SO^2 + H,SO^2$ Hydra ammona bisulphete.

267. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Na;\ SO^2 \end{array}\right.$

268. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Mg;\ SO^2 \end{array}\right.$

269. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ U;\ SO^2 \end{array}\right.$

270. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Mn;\ SO^2 \end{array}\right.$

271. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Fe;\ SO^2 \end{array}\right.$

272. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Fec;\ SO^2 \end{array}\right.$

273. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Pb;\ SO^2 \end{array}\right.$

274. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Zn;\ SO^2 \end{array}\right.$

275. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Co;\ SO^2 \end{array}\right.$

276. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Ni;\ SO^2 \end{array}\right.$

277. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Cuc;\ SO^2 \end{array}\right.$

278. $\left\{\begin{array}{l} ZH^4;\ SO^2 \\ Hgc;\ SO^2 \end{array}\right.$

This group consists of double sulphates, in each of which normal ammonium is one of the positive radicals. The systematic names are omitted, to save room. They may be found by substituting the name of the characteristic radical in each salt for the word *hydra* in the model name added to No. 266, thus:

No. 271 is Ferrous ammona bisulphete.
272 is Ferric ammona bisulphete.

The ordinary name of No. 266 is bisulphate of ammonia = $NH^4O,SO^3 + HO,SO^3$. The usual name of No. 267 is sulphate of soda and ammonia.

GROUP D.

279. $ZH^4;\ SO^2 + 3(Alc,SO^2) + Aq^{12}$.
280. $ZH^4;\ SO^2 + 3(Crc,SO^2) + Aq^{12}$.
281. $ZH^4;\ SO^2 + 3(Mnc,SO^2) + Aq^{12}$.
282. $ZH^4;\ SO^2 + 3(Fec,SO^2) + Aq^{12}$.

This group consists of the compounds that are commonly called AMMONIA-ALUMS. The systematic name for No. 279 is, ammona sulphete tris alic sulphete cum aquabete. Its common name is sulphate of alumina and ammonia, with 24 atoms of water of crystallization,

$$= (NH^4O,SO^3) + (Al^2O^3,3SO^3) + 24Aq. \quad \textit{Gmelin.}$$
$$= (HO,SO^3,HAd + 6Aq) + Al^2O^3,3SO^3 + 18Aq. \quad \textit{Kane.}$$

These formulæ apply equally to the other examples, only changing Al^2 for Cr^2, Mn^2, and Fe^2; for in all these salts, the usual theory of chemistry assumes the existence of a tersulphate of the sesquioxide of the characterizing metal.

GROUP E.

283.	$\left\{\begin{array}{c} ZH^4,SO^2 \\ Uc,SO^2 \\ (Uc,HO)^2 \end{array}\right\}$	Uric ammona bisulphete, bis uric hydrate.
284.	$\left\{\begin{array}{c} ZH^4,SO^2 \\ ZH^4,NiO \end{array}\right\}$	Ammona sulphete cum ammona niccolousate.
285.	$\left\{\begin{array}{l} (ZH^3Cuc,SO^2)^2 \\ ZH^4,ZH^4O \end{array}\right\}$	Bis cupricam sulphete cum ammona ammonate.
286.	$\left\{\begin{array}{l} ZH^3Cuc,\ SO^2 \\ Cuc\quad ,SO^2 \end{array}\right\}$	Cupricam cupric bisulphete.
287.	$\left\{\begin{array}{r} ZHHg^3,SO^2 \\ Hg,HO \end{array}\right\}$	Merousim sulphete cum merous hydrate.
288.	$\left\{\begin{array}{r} ZHHgc^3,SO^2 \\ Hgc,HO \end{array}\right\}$	Mericcim sulphete cum meric hydrate.
289.	$\left\{\begin{array}{r} ZH^3Ptc,SO^2 \\ Ptc,SO^2 \end{array}\right\}$	Platicam sulphete cum platic sulphete.

USUAL NAMES AND FORMULÆ.—283, Sulphate of uranic oxide and ammonia = urano-ammonic sulphate = $NH^4O,SO^3 + U^2O^3,SO^3 + 2Aq$. *Gmelin.* It may be well to put here the usual name of No. 269: it is Sulphate of uranous oxide and ammonia = uranoso-ammonic sulphate = $NH^4O,SO^3 + UO,SO^3$. *Gmelin.* 284, Niccolo-sulphate of ammonia = $NH^4O,NiO = NH^4O,SO^3$. *Gmelin.* 285, Cupro-sulphate of ammonia; cuprum ammoniacale = $NH^3,CuO + NH^4O,SO^3$. *Gmelin.* 286, Sesquibasic sulphate of cupric oxide and ammonia = $NH^3,2CuO,2SO^3$, or $NH^3,CuO,SO^3 + CuO,SO^3$. *Gmelin.* Observe, that Nos. 257, 277, 285 and 286, are all ammoniacal sulphates of copper. 287, Trisulphate of mercurous oxide with mercurous amide = $Hg^2,NH^2 + 3Hg^2O,SO^3$. *Gmelin.* 288, Trisulphate of mercuric oxide with mercuric amide, or ammoniacal turpethum = $Hg,NH^2 + 3HgO,SO^3$. *Gmelin.* 289. See Platinum, No. 81.]

Sulphates of Organic Vice-ammons and Vice-amids.

290. $ZH^3,CH^3;\ SO^2$. Methylam sulphete.
291. $ZH^3,C^2H^3;\ SO^2$. Acetylam sulphete.
292. $ZH^3,C^6H^5;\ SO^2$. Phenylam sulphete.
293. $ZH^3,C^6H^4Cl;\ SO^2$. Chloric-phenylam sulphete.
294. $ZH^3,C^6H^4I;\ SO^2$. Iodic-phenylam sulphete.
295. $ZH^2,C^6H^5, Cuc;\ SO^2$. Cupric-phenylam sulphete.
296. $ZH^3,C^7H^7;\ SO^2$. Toluenylam sulphete.
297. $\left\{\begin{array}{r}ZH,C^8H^3;\ SO^2\\ H;\ SO^2\end{array}\right\}$ Hydra indylac sulphenote.
298. $\left\{\begin{array}{r}ZH,C^8H^3;\ SO^2\\ Pb;\ SO^2\end{array}\right\}$ Plumba indylac sulphenote.
299. $\left\{\begin{array}{r}ZH^3,C^8H^3;\ SO^2\\ H;\ SO^2\end{array}\right\}$ Hydra indylam sulphenote.
300. $\left\{\begin{array}{l}ZH^3,C^{10}H^7\ ;\ SO^2\\ ZH^2\ ;\ SO^2\end{array}\right\}$ Naphtylam amida sulphenote.
301. $\left\{\begin{array}{r}Z,C^2H^2,C^7H^5;\ SO^2\\ C^6H^5;\ SO^2\end{array}\right\}$ Succinylic-benzylac sulphete cum phenyla sulphete.
302. $\left\{\begin{array}{r}Z,C^2H^2,C^2H^2;\ SO^2\\ C^6H^5;\ SO^2\end{array}\right\}$ Succinylec sulphete cum phenyla sulphete.
303. $\left\{\begin{array}{r}Z,C^7H^5,C^7H^5;\ SO^2\\ C^6H^5;\ SO^2\end{array}\right\}$ Benzylec sulphete cum phenyla sulphete.
304. $\left\{\begin{array}{r}Z,C^7H^5,C^2H^3;\ SO^2\\ C^6H^5;\ SO^2\end{array}\right\}$ Acetylic-benzylac sulphete cum phenyla sulphete.
305. $\left\{\begin{array}{r}ZC^{10}H^{11},C^7H^5;\ SO^2\\ C^6H^5;\ SO^2\end{array}\right\}$ Cumylic-benzylac sulphete cum phenyla sulphete.
306. $ZH,(CH^3)^3;\ SO^2 + 3(Alc,SO^2) + Aq^{12}$ = Methylim sulphete tris alic sulphete cum aquabete.

USUAL NAMES AND FORMULÆ.—290, Sulphate of methylamine = $C^{2}H^{5}N,HSO^{4}$. 291, Neutral sulphate of acetosamine = $2C^{4}H^{5}N,2HO,S^{2}O^{6}$, *Gerhardt*. 292, See aniline 24]. 293, See aniline 26]. 294, See aniline 27]. 295, See aniline 25]. 296, Sulphate of toluidine = $2C^{14}H^{9}N,S^{2}O^{6},2HO$, *Gerhardt*. 297, See indigo, 48]. 298, See indigo, 49]. 299, See indigo, 46]. 300, Bisulphate of seminaphtalidam, or bisulphate of azonaphtylamine = $C^{20}H^{10}N^{2},S^{2}O^{6},2HO$, *Gerhardt*. See No. 208.

$$301.\ \left\{\begin{array}{l}\text{Diazoture of sulphophenyle, of}\\ \quad\text{benzoile, and of succinyle}\\ \quad = C^{60}H^{24}N^{2}S^{4}O^{16}\end{array}\right. = N^{2}\left\{\begin{array}{ll}C^{14}H^{5} & O^{2}\\ C^{14}H^{5} & O^{2}\\ C^{12}H^{5}S^{2} & O^{4}\\ C^{12}H^{5}S^{2} & O^{4}\\ C^{8}H^{4} & O^{4}\end{array}\right. \quad \textit{Gerhardt.}$$

$$302.\ \left\{\begin{array}{l}\text{Azoture of sulphophenyle, and}\\ \quad\text{of succinyle} = C^{20}H^{9}NS^{2}O^{8}\end{array}\right. = N\left\{\begin{array}{ll}C^{12}H^{5}S^{2}O^{4} & \\ C^{8}H^{4} & O^{4}\end{array}\right. \quad \textit{Gerhardt.}$$

$$303.\ \left\{\begin{array}{lll}\begin{array}{l}\text{Dibenzo - sulphophenylamide}\\ \quad = (C^{40}H^{15}N^{2}O^{8}N),\ \text{or,}\end{array} & \left\{\begin{array}{ll}C^{14}H^{5} & O^{2}\\ C^{14}H^{5} & O^{2}\\ C^{12}H^{5},2SO^{2} & \end{array}\right\}N & \textit{Miller.}\\ \begin{array}{l}\text{Azoture of sulphophenyle and}\\ \quad\text{of benzoile} = C^{20}H^{15}NSO^{4}\end{array} & = N\left\{\begin{array}{l}C^{6}H^{5}SO^{2}\\ C^{7}H^{5}O\\ C^{7}H^{5}O\end{array}\right. & \textit{Gerhardt.}\\ \begin{array}{l}\text{Azoture of sulphophenyle, of}\\ \quad\text{benzoile, and of benzoile}\\ \quad = C^{40}H^{15}NS^{2}O^{8}\end{array} & = N\left\{\begin{array}{l}C^{12}H^{5}S^{2}O^{4}\\ C^{14}H^{5}O^{2}\\ C^{14}H^{5}O^{2}\end{array}\right. & \textit{Gerhardt.}\end{array}\right.$$

For an account of the preparation of this salt, see No. 327.

$$304.\ \left\{\begin{array}{l}\text{Azoture of sulphophenyle, of}\\ \quad\text{benzoile, and of acetyle}\\ \quad = C^{30}H^{13}NS^{2}O^{8}\end{array}\right. = N\left\{\begin{array}{l}C^{12}H^{5}S^{2}O^{4}\\ C^{14}H^{5}O^{2}\\ C^{4}H^{3}O^{2}\end{array}\right. \quad \textit{Gerhardt.}$$

$$305.\ \left\{\begin{array}{ll}\begin{array}{l}\text{Azoture of sulphophenyle, of}\\ \quad\text{benzoile, and of cumyle}\\ \quad = C^{46}H^{21}NS^{2}O^{8}\end{array} & = N\left\{\begin{array}{l}C^{12}H^{5}S^{2}O^{4}\\ C^{14}H^{5}O^{2}\\ C^{20}H^{11}O^{2}\end{array}\right. \quad \textit{Gerhardt.}\\ \quad = C^{23}H^{21}NSO^{4} & = N\left\{\begin{array}{l}C^{6}H^{5}SO^{2}\\ C^{7}H^{5}O\\ C^{10}H^{11}O\end{array}\right. \quad \textit{Gerhardt.}\end{array}\right.$$

306. The alum of trimethylamine

$$= SO^{3},N(C^{2}H^{3})^{3}HO + 3SO^{3},Al^{2}O^{3} + 24\ \text{aq.}$$

$$= \left\{\begin{array}{r}\left.\begin{array}{r}N(C^{2}H^{3})^{3}H.O\\ \text{al O}\end{array}\right\}S^{2}O^{6}\\ \left.\begin{array}{r}\text{al O}\\ \text{al O}\end{array}\right\}S^{2}O^{6}\end{array}\right. + 24\ \text{aq.} \quad \textit{Gerhardt.}$$

Professor Miller quotes No. 303 as an example of a "tertiary amide, in which each equivalent of the hydrogen of ammonia is displaced by an equivalent of an organic radicle," and he apologizes for its "inharmonious and unwieldy name." It would, perhaps, have better suited the circumstances if he had apologized for the wildness of the theory which gave rise not only to the name, but to the formulæ; or does Professor Miller really believe in the proposition, that such compounds as $C^{14}H^5O^2$, and $C^{14}H^5O^2$, and (more wonderful still) $C^{12}H^5S^2O^4$, can each replace one of the three atoms of hydrogen which belong to ammonia, and in company with the nitrogen, constitute an *ammonia*, *merely an ammonia*, and not a salt? Does he believe that the formulæ which I have quoted from Gerhardt to represent the compound No. 301, prove the constitution of that compound to be that of an ammonia? It seems to me, that this new "ammonia type" of Gerhardt's is a press by means of which anything you wish to put out of your way—hydrogen, metals, hydrocarbons, metalloids, oxygen, nitrogen, and everything else—is to be screwed into the form of an "ammonia," without regard to possibility, necessity, or utility. It is a short and sharp way of getting rid of troublesome things, just as novelists and dramatists kill off characters who become superfluous. The ammonia type is an accommodating thing in its own way. Just as the bed of Procrustes suited all men, provided the short men were racked longer and the long men were cut shorter, so the ammonia type suits all nitrogenous salts, provided they are properly trimmed to fit it.

The Polythionates of Ammonia.

This section includes the salts that are formed by dry ammonia gas with anhydrous oxysulphur acids.

307.	$ZH^2,SO + ZH^4,SO$ . .	Amida sulphate cum ammona sulphate.
308.	$ZH^2,SO + H,SO$ . .	Amida sulphate cum hydra sulphate.
309.	$ZH^2,SO + ZH^4Cl$ . .	Amida sulphate cum ammona chlora.
310.	$ZH^4,ZH^4;\ S^2O^3$ . . .	Ammona ammona sulphenite.
311.	$H,ZH^4;\ S^2O^3$	Hydra ammona sulphenite.
312.	$H,ZH^2;\ S^2O^3$	Hydra amida sulphenite.
313.	$ZH^4,ZH^2;\ S^2O^3$ . . .	Ammona amida sulphenite.
314.	$\left\{\begin{matrix} H;\ ZH^2;\ S^2O^3 \\ ZH^4;\ ZH^2;\ S^2O^3 \end{matrix}\right\}$ . .	Hydra amida sulphenite cum ammona amida sulphenite.
315.	$ZH^4,S^2O^2 + ZH^2,S^2O^2$.	Ammona sulphenete cum amida sulphenete.
316.	ZH^4,S^2O^3	Ammona sulphenite.
317.	ZH^4,S^3O^3	Ammona sulphinite.

317a. $ZH^4,SO^2 + (HSO)^2$. Ammona sulphete bis hydra sulphate.

318. $\left\{\begin{matrix} ZH^4SO + HSO \\ (ZH^4)^2 ; S^4O^3 \end{matrix}\right\}$ . . Hydra ammona bisulphate cum ammonen sulphonite.

319. $(ZH^4)^2,S^4O^3 + \frac{1}{2}Aq$ . . Tris ammonen sulphonite cum aquate.

USUAL NAMES AND FORMULÆ.

307. $ZH^2,SO + ZH^4,SO$ . . Amida sulphate cum ammona sulphate.

According to Miller, this compound is produced by mixing dry sulphurous acid gas SO with an *excess* of dry ammoniacal gas. Two volumes of SO and four volumes of ZH^2H, that is to say, two atoms of each compound, combine to form this salt. Miller calls it sulphurous ammonide = H^3N,SO^2. Gmelin does not admit of its existence.

308. $ZH^2,SO + H,SO$ . . Amida sulphate cum hydra sulphate.

Miller informs us, that this compound is produced when an *excess* of dry sulphurous acid gas is mixed with dry ammoniacal gas. Gmelin states, on the authority of Rose, that in whatever proportions the two gases are mixed, they always condense in equal volumes. Miller's formula is $H^3N,2SO^2$. Gmelin gives it two formulæ, $NH^3,2SO^2$ and NH^3,SO,SO^3, and names it sulphit-ammon.

It differs from bisulphite of ammonia, No. 311, by one atom of water, thus—

$$\left.\begin{matrix} ZH^2,SO + HSO \\ H^2 \quad O \end{matrix}\right\} = ZH^4SO^2 + HSO.$$

When it is dissolved in water, it speedily produces sulphate and trithionate of ammonia—

$$\left.\begin{matrix} ZH^2,SO + HSO \\ ZH^2,SO + HSO \\ H^2 \quad O \\ H^2 \quad O \end{matrix}\right\} = \left\{\begin{matrix} \left.\begin{matrix} ZH^4,SO^2 \\ HSO \\ HSO \end{matrix}\right\} = \text{Trithionate of ammonia.} \\ ZH^4,SO^2 \quad = \text{Sulphate of ammonia.} \end{matrix}\right.$$

Compare the note descriptive of No. 315.

309. $ZH^2,SO + ZH^4Cl$. Amida sulphate cum ammona chlora.

A mixture of sal-ammoniac and sulphamide = $NH^2,SO^2 + NH^4Cl$, *Gmelin*. A white soluble powder. Sulphamide = ZH^2,SO has not been isolated.

310. $ZH^4 ; ZH^4 ; S^2O^3$ . . Ammona ammona sulphenite.

Analytical formula = $ZH^4; SO + ZH^4,SO^2$. Usual name: Neutral sulphite of ammonia.

311. $H; ZH^4; S^2O^3$ . . Hydra ammona sulphenite.

Analytical formula = $ZH^4,SO + H,SO^2$. Usual name: Bisulphite of ammonia.

312. $H; ZH^2; S^2O^3$ . . Hydra amida sulphenite.

A hypothetical compound; not yet produced. Its supposed constitution is = $ZH^2SO + H^rSO^2$; the H^r being replaceable by a positive radical. Usual name: Sulphamic acid = HO,H^2N,S^2O^5, *Miller*. The formula of the sulphamates, according to the radical theory, is $ZH^2SO + M^rSO^2$, or $M^r; ZH^2; S^2O^3$. That is to say, they are common bibasic sulphites, in which ZH^2 is constantly one of the two basic radicals. According to Dr. Miller's formula, this acid is what I may call an amidated hyposulphate; but we have not the slightest evidence to show that the amidogen in this salt acts as part of the acid radical, nor that the salt is a hyposulphate. In fact, if ZH^2 be admitted to be a basic radical, then the existence of two positive radicals in the salt is sufficient proof that it is not a hyposulphate. See the note on oxamic acid, page 195, and in the oxamates, page 226.

313. $ZH^4; ZH^2; S^2O^3$ . . Ammona amida sulphenite.

Analytical formula = $ZH^2,SO + ZH^4,SO^2$. Produced by transmitting a current of dry ammoniacal gas = ZH^2H over anhydrous sulphuric acid = S,SO^3, keeping the latter in excess. Common names: Sulphuric ammonide or Sulphat ammon = H^3N,SO^3, *Miller*. Sulphate of ammon = NH^3,SO^3, *Gmelin*. Sulphamide, *Dumas*. Sulphat ammon, *Rose*. It is, of course, the ammonium salt of the hypothetical sulphamic acid, No. 312; and it is sometimes called the sulphamate of ammonia. Gmelin describes a "deliquescent sulphate of ammon," which seems to agree with the formula $ZH^4; ZH^2; S^2O^3 + \frac{1}{2}aq$.

314. $\left\{\begin{matrix} H; ZH^2; S^2O^3 \\ ZH^4; ZH^2; S^2O^3 \end{matrix}\right\}$. Hydra amida sulphenite cum ammona amida sulphenite.

"According to Jacquelain, this compound may be procured in beautiful transparent crystals by transmitting the vapour of anhydrous sulphuric acid into ammoniacal gas in excess; the solid compound thus obtained is fused in a current of dry ammonia, and dissolved in water. The crystals obtained on evaporation consist of $3(H^3N) + 4SO^3$. Although the solution of this compound has an acid reaction, it gives no precipitate with salts of baryta." *Miller*.

Compare the three formulæ 312, 313, 314. It is evident that 314 represents a double salt composed of 312 + 313. It is what might be called, according to the ordinary theory, the acid sulphamate of ammonia;

but Miller does not give it that name. The reader will find it important to notice the evidence afforded by this salt of the existence of double sulphites. The presence of the replaceable atom of H^r is the cause of the acid reaction. The non-precipitation of salts of baryta MAY be due to the formation of a soluble double salt agreeing with the formula—

$$\left\{\begin{matrix} Ba; ZH^2; S^2O^3 \\ ZH^4; ZH^2; S^2O^3 \end{matrix}\right\}.$$

315. $\left\{\begin{matrix} ZH^4; S^2O^2 \\ ZH^2; S^2O^2 \end{matrix}\right\}$ . . . Ammona sulphenete cum amida sulphenete.

I have alluded at page 170 to the existence of a class of oxysulphur salts which agree with the formula $H^r,SO + SO$ or H^r,S^2O^2. This compound may be a double salt of that series, but its composition is uncertain. I have grouped the elements into a different formula at No. 308. Other views of the composition of this salt are described in Gmelin's Handbook of Chemistry, vol. ii., p. 456. It is possible that salts may exist which agree with both formulæ.

316. $ZH^4; S^2O^3$ . . . . Ammona sulphenite.

A compound containing S^2O^3, with one positive radical, constituting what Gmelin properly calls a hyposulphate. His formula is NH^4O,S^2O^5, (with aq^1, which I have omitted in the above formula).

317. $ZH^4; S^3O^3$ . . . Ammona sulphinite.

317*a*. $\left\{\begin{matrix} ZH^4SO^2 \\ (HSO)^2 \end{matrix}\right\}$ . . Ammona sulphete bis hydra sulphate.

Miller quotes H^4NO,S^3O^5 as the formula of the trithionate of ammonia which is produced by the decomposition of the salt No. 308. This formula would require No. 317; but in the presence of water, the compound that would be produced is that which is represented by the formula No. 317*a*. Consult the Theory of the Trithionates, page 168.

318. $\left\{\begin{matrix} ZH^4SO + HSO \\ (ZH^4)^2; S^4O^3 \end{matrix}\right\}$. Ammona hydra bisulphate cum ammonen sulphonite.

319. $(ZH^4)^2; S^4O^3 + \frac{1}{3}aq$ Tris ammonen sulphonite cum aquate.

Gmelin's hyposulphite of ammonia $= 3(NH^4O,S^2O^2) + HO$, admits of explanation either by No. 318 or 319, according as it is considered to be a hydrated or an anhydrous salt. See the Theory of the Hyposulphites, page 160.

Sulphites containing Vice-Amids and Vice-Ammons.

The conditions of the existence of a sulphite are that it shall contain two positive radicals, two atoms of sulphur, and three atoms of oxygen.

320.	CH^3;	ZH^2;	S^2O^3	Methyla amida sulphenite.
320^a.	C^7H^5;	ZH^4;	S^2O^3	Benzyla ammona sulphenite.
321.	H;	ZH, C^6H^5;	S^2O^3	Hydra phenylac sulphenite.
322.	ZH^4;	ZH, C^6H^5;	S^2O^3	Ammona phenylac sulphenite.
323.	Ag;	ZH, C^6H^5;	S^2O^3	Argenta phenylac sulphenite.
324.	Ba;	ZH, C^6H^5;	S^2O^3	Baryta phenylac sulphenite.
325.	C^7H^5;	ZH, C^6H^5;	S^2O^3	Benzyla phenylac sulphenite.
326.	$C^{10}H^{11}$;	ZH, C^6H^5;	S^2O^3	Cumyla phenylac sulphenite.
327.	Ag;	ZC^7H^5, C^6H^5;	S^2O^3	Argenta benzylic-phenylac sulphenite.
328.	C^7H^5;	ZAg, C^6H^5;	S^2O^3	Benzyla argentic-phenylac sulphenite.
329.	H;	$ZH, C^{10}H^7$;	S^2O^3	Hydra naphtylac sulphenite.
330.	K;	$ZH, C^{10}H^7$;	S^2O^3	Potassa naphtylac sulphenite.
331.	K;	ZH, C^7H^7;	S^2O^3	Potassa toluenylac sulphenite.
332.	ZH^4;	ZH, C^7H^7;	S^2O^3	Ammona toluenylac sulphenite.
333.	$(ZH^3,C^8H^3)^2$;		S^2O^3	Indylamen sulphenite.

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320. CH^3; ZH^2; S^2O^3. Methyla amida sulphenite. Analytical formula $= ZH^2SO + CH^3,SO^2$. This salt corresponds to 313, with the exception that the replaceable positive radical is CH^3 instead of ZH^4. It is, therefore, according to the usual theory, the sulphamate of methyl, the trivial name of which is sulphomethylane. Gmelin's new German systematic name is Schwefel-Formamester $= C^2H^3Ad, 2SO^3$. He also quotes the following formulæ $= C^2H^5NS^2O^6$ and C^2H^3O,S^2AdO^5. Gerhardt's name and formulæ are, Sulphamethylane, or sulphamate of methyl $= C^2H^5NS^2O^6$ $= \left\{\begin{matrix} NH^2 & (SO^2)^2O \\ & C^2H^3O \end{matrix}\right\}$; and he adds the information, that "sulphamic acid represents the hydrate of an oxide of ammonium in which H is replaced by SO^2." I might reasonably inquire, whether "the hydrate of an oxide of ammonium," in which H has been replaced by SO^2, STILL REMAINS "the hydrate of an oxide" of ammonium? For my part, I consider an ammonium having the formula (ZH,H,SO^2,SO^2) to be a monster whose existence is impossible.

The following is Professor Gregory's account of this compound: "When a current of ammonia is made to act on the neutral sulphate of methyl, there is produced a crystalline compound $C^2H^5NS^2O^6$, which has been called sulphamethylane, and may be viewed as oxamethylane, in which sulphamide, SO^2,NH^2, has been substituted for oxamide, C^2O^2, NH^2; or SO^2, for C^2O^2. It may also be considered, if oxamethylane be the oxamate of oxide of methyl, $C^2H^3O + C^4H^2NO^5$, as composed of oxide of methyle and a peculiar acid, formed of hyposulphuric acid and amide, or rather of sulphuric acid and sulphamide, and which may be called sulphamic acid; and its formula will be $C^2H^3O + (S^2O^5, NH^2)$, or $C^2H^3O + (SO^3 + NH^2,SO^2)$. On this view, sulphamethylane is the sulphamate of oxide of methyle."—*Handbook of Organic Chemistry* (1856), page 179.

This paragraph contains an excellent summary of the views that are now entertained by organic chemists in respect to this compound, and these views manifest a state of bewilderment which is calculated to inspire little confidence in the minds of chemical students.

320^a. C^7H^5; ZH^4; S^2O^3, Benzyla ammona sulphate.
Usual Name: Sulphite of benzosum and of ammonium

$$= C^7H^5(NH^4)O,SO^2 = O^2 \left\{\begin{array}{l} SO \\ C^7H^5 \\ NH^4. \end{array}\right. \quad \textit{Gerhardt.}$$

321. H; ZH,C^6H^5; S^2O^3 Hydra phenylac sulphenite. Analytical formula $= ZH,C^6H^5$; $SO + H^rSO^2$. Compare this formula with No. 312. The salts are similarly constituted, excepting that one of them contains amid as a constant basic radical, where the other has phenylac. In both salts there is one replaceable atom of hydrogen, H^r, which gives rise to a series of neutral sulphites.

Usual names.—Sulphanilic acid; anilamic sulphuric acid, or anilosulphamic acid $= C^{12}H^7NS^2O^6 = HO . SO^3$; $C^{12}H^6N,SO^2 = HSO^4C^{12}H^6N,SO^2$

$$= HO . S \left\{\begin{array}{l} O^2 \\ And \end{array}\right. SO^3. \quad \textit{Hofmann.}$$

Sulphanilic acid, or phenyl-sulphamic acid $= C^{12}H^7NS^2O^6$, *Gerhardt.* Sulphanilic acid $= HO,C^{12}H^6NS^2O^5 = HO,C^{12}H^5,HN,S^2O^5$, *Miller.* Sulphanilic acid is formed by heating aniline with strong sulphuric acid.

322. ZH^4; ZH,C^6H^5; S^2O^3, Ammona phenylac sulphenite.
323. Ag; ZH,C^6H^5; S^2O^3, Argenta phenylac sulphenite.
324. Ba; ZH,C^6H^5; S^2O^3, Baryta phenylac sulphenite.
325. C^7H^5; ZH,C^6H^5; S^2O^3, Benzyla phenylac sulphenite.
326. $C^{10}H^{11}$; ZH,C^6H^5; S^2O^3, Cumyla phenylac sulphenite.

These five salts are formed by the replacement of H, in the so-called sulphanilic "acid" No. 321, by the positive radicals that are exhibited by the different formulæ. Of course, these are the salts that are commonly called sulphanilates. I will nevertheless quote the ordinary names and formulæ of each salt.

322, Sulphanilate of ammonia = $C^{12}H^{6}(NH^{4})NS^{2}O^{6}$, *Gerhardt*,

$$= NH^{4}O,S\left\{\begin{matrix} O^{2} \\ \text{And} \end{matrix}\right. SO^{3}, \textit{Hofmann.}$$

323, Sulphanilate of silver = $C^{12}(H^{6}Ag)NS^{2}O^{6}$, *Hofmann*. 324, Sulphanilate of barytes = $C^{12}(H^{6}Ba)NS^{2}O^{6}$, *Hofmann*. 325, Analytical formulæ, $ZH,C^{6}H^{5}; SO+C^{7}H^{5}; SO^{2}$. *Usual names*: Benzo-sulphophenylamide = $\left\{\begin{matrix} C^{12}H^{5},2SO^{2} \\ C^{14}H^{5}O^{2} \\ H \end{matrix}\right\} N$, *Miller*. Azoture of sulphophenyle, of benzoile, and of hydrogen = $N\left\{\begin{matrix} C^{6}H^{5}SO^{2} \\ C^{7}H^{5}O \\ H \end{matrix}\right.$ *Gerhardt*. The following reaction exhibits the formation of this salt from No. 342, when acted upon by the compound $C^{7}H^{5}, ClO$ = Benzyla chlorate, commonly called chloride of benzoyl.

$$\text{No. 342}\left.\begin{matrix} \left\{\begin{matrix} ZH,C^{6}H^{5};\ SO \\ Ag;\ SO \end{matrix}\right\} \\ C^{7}H^{5};\ ClO \end{matrix}\right\} = \left\{\begin{matrix} \left.\begin{matrix} ZH,C^{6}H^{5};\ SO \\ C^{7}H^{5};\ SO^{2} \end{matrix}\right\} \\ Ag;\ Cl \end{matrix}\right. = \text{No. 325.}$$

326, Azoture of sulphophenyle, of cumyle, and of hydrogen = $C^{16}H^{17}NSO^{3}$ = $N\left\{\begin{matrix} C^{6}H^{5}SO^{2} \\ C^{10}H^{11}O \\ H \end{matrix}\right.$ *Gerhardt*.

It is amusing to notice the varieties in the formulæ which the ingenuity of chemists has provided for the sulphanilates. The salts are evidently formed on a single model, but the formulæ are very agreeably diversified, and all in accordance with the well-known philosophical axiom, that "the farthest way round is the nearest way there."

327, $Ag; ZC^{7}H^{5},C^{6}H^{5}; S^{2}O^{3}$. Argenta benzylic-phenylac sulphenite.

328. $C^{7}H^{5}; ZAg,C^{6}H^{5}; S^{2}O^{3}$. Benzyla argentic-phenylac sulphenite.

Nos. 327 and 328 are different formulæ to represent the same compound. The salt differs from No. 323, in having the amidec $ZC^{7}H^{5},C^{6}H^{5}$, instead of the amidac $ZH,C^{6}H^{5}$. It may also be compared with the salt No. 325, from which it is prepared, and from which it differs by containing $ZAg,C^{6}H^{5}$ instead of $ZH,C^{6}H^{5}$. Whether the silver acts as a base *per se*, or is in the condition of argentic-phenylac is undetermined. The following reactions are interesting, but undecisive in this particular:

$$\left.\begin{matrix} C^{7}H^{5};\ ZH,C^{6}H^{5};\ S^{2}O^{3} \\ Ag;\ NO^{5} \end{matrix}\right\} = \left\{\begin{matrix} C^{7}H^{5};\ ZAg,C^{6}H^{5};\ S^{2}O^{3} \\ H;\ NO^{5}. \end{matrix}\right.$$

$$\left.\begin{matrix} C^{7}H^{5};\ ZAg.C^{6}H^{5};\ S^{2}O^{3} \\ C^{7}H^{5};\ ClO \end{matrix}\right\} = \left\{\begin{matrix} ZC^{7}H^{5},C^{7}H^{5};\ SO^{2} \\ C^{6}H^{5};\ SO^{2} \end{matrix}\right\} + AgCl.$$

The product of the last reaction is the salt No. 303.

Usual name of No. 327:—

$$\text{Benzosulphophenylargentamide} = \left.\begin{matrix} C^{12}H^{5},2SO^{2} \\ C^{14}H^{5}O^{2} \\ Ag \end{matrix}\right\} N, \textit{Miller.}$$

$$\left.\begin{array}{c}\text{Azoture of sulphophenyle, of}\\ \text{benzoile and of silver.}\end{array}\right\} = N\left\{\begin{array}{l}C^6H^5SO^2\\ C^7H^5O\\ \quad Ag.\end{array}\right. \textit{Gerhardt.}$$

329, $H; ZH,C^{10}H^7; S^2O^3$, Hydra naphtylac sulphenite; Analytical formula = $ZH,C^{10}H^7; SO + H,SO^2$.

Thionaphtamic acid = $C^{20}H^9NS^2O^6$, *Gerhardt*. Compare with No. 337.

330, $K; ZH,C^{10}H^7; S^2O^3$; Potassa naphtylac sulphenite.

Thionaphtamate of potash, *Gerhardt*. Similar salts are formed with ZH^4,Ba,Pb, instead of K. Compare with No. 338.

331. $K; ZH,C^7H^7; S^2O^3$ . . . Potassa toluenylac sulphenite.
332. $ZH^4; ZH,C^7H^7; S^2O^3$ . . Ammona toluenylac sulphenite.

These salts are called thiotolamates or thiotoluolates. Formulæ: $C^{14}NH^8KS^2O^6$ and $C^{14}NH^8(NH^4)2SO^3$, *Gmelin*. The thiotolamic acid has not been isolated.

333. $(ZH^3,C^8H^3)^2; S^2O^3$, Indylamen sulphenite. See Indigo, No. 50.]

Hyposulphates containing Vice-Amids and Vice-Ammons.

A hyposulphate must contain two atoms of sulphur, three atoms of oxygen and one positive radical.

334. $\left\{\begin{array}{ll}ZH,C^6H^5 & ; S^2O^3\\ H & ; S^2O^3\end{array}\right\}$ Hydra phenylac bisulphenite.

335. $\left\{\begin{array}{ll}ZBa,C^6H^5 & ; S^2O^3\\ Ba & ; S^2O^3\end{array}\right\}$ Baryta barytic-phenylac bisulphenite.

336. $\left\{\begin{array}{ll}ZAg,C^6H^5 & ; S^2O^3\\ Ag & ; S^2O^3\end{array}\right\}$ Argenta argentic-phenylac bisulphenite.

337. $\left\{\begin{array}{ll}ZH^2,(C^{10}H^7)^2 & ; S^2O^3\\ ZH^2 & ; S^2O^3\end{array}\right\}$ Naphtylem amida bisulphenite.

338. $\left\{\begin{array}{ll}ZH^2(C^{10}H^7)^2 & ; S^2O^3\\ ZAg^2 & ; S^2O^3\end{array}\right\}$ Naphtylem argentec bisulphenite.

339. $ZH^3Zn; S^2O^3 + ZH^2H$ Zincam sulphenite cum amida hydra.
340. $ZH^3Ni; S^2O^3 + 2ZH^2H$ Niccolousam sulphenite bis amida hydra.

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334. $H; ZH,C^6H^5; (S^2O^3)^2$, Hydra phenylac bisulphenite.

$$\begin{array}{c}\text{Analytical formula}\\ \text{See page 172.}\end{array}\left\{\begin{array}{r}ZH,C^6H^5; SO^2 + SO\\ H; SO^2 + SO\end{array}\right\}$$

Compare this compound with No. 321. The basic radicals H and

ZH,C^6H^5, are combined in 321 with S^2O^3, in 334 with twice S^2O^3; or, reversing the standard, we have, to the same quantity of S^2O^3, in 321, *four* basic radicals, in 334 two basic radicals. Hence, 321 is a sulphite and 334 a double hyposulphate. This compound is produced by heating dry sulphanilic acid with fuming sulphuric acid. It was discovered by Buckton and Hofmann, who call it disulphanilic acid, and give it the formula $C^{12}H^7NS^4O^{12}$. According to these chemists, it is a peculiar and perfectly new bibasic acid, which forms salts that agree with the formula $C^{12}(H^5M^2)NS^4O^{12}$. There is, however, no evidence to prove the existence of this peculiar acid, or to warrant the formulating of the salts which it produces as if they contained any new acid. They appear to be double hyposulphates and nothing else.

$$335.\ \left\{\begin{array}{r}ZBa,C^6H^5;\ S^2O^3\\ Ba;\ S^2O^3\end{array}\right\}\ \text{Baryta barytic-phenylac bisulphenite.}$$

$$336.\ \left\{\begin{array}{r}ZAg,C^6H^5;\ S^2O^3\\ Ag;\ S^2O^3\end{array}\right\}\ \text{Argenta argentic-phenylac bisulphenite.}$$

These are salts of the so-called "disulphanilic acid," No. 334. They can be formulated in a more simple manner thus:

334. $ZH^2;\ C^6H^5;\ (S^2O^3)^2$ = Amida phenyla bisulphenite.
335. $ZBa^2;\ C^6H^5;\ (S^2O^3)^2$ = Barytec phenyla bisulphenite.
336. $ZAg^2;\ C^6H^5;\ (S^2O^3)^2$ = Argentec phenyla bisulphenite.

But these formulæ are founded on the notion of the complete disruption of the aniline; and I cannot tell, from the account which has been published by Messrs. Buckton and Hofmann, whether this disruption takes place or not. These formulæ account, in a very simple manner, for the bibasic property of disulphanilic acid.

$$337.\ \left\{\begin{array}{ll}ZH^2,(C^{10}H^7)^2; & S^2O^3\\ ZH^2; & S^2O^3\end{array}\right\}\ \text{Naphtylem amida bisulphenite.}$$

$$338.\ \left\{\begin{array}{ll}ZH^2(^{10}H^7)^2; & S^2O^3\\ ZAgAg; & S^2O^3\end{array}\right\}\ \text{Naphtylem argentec bisulphenite.}$$

When thionaphtamic acid (No. 329) is prepared, its mother-liquor yields a compound having different properties, but the same percentage composition as that acid. See Gerhardt, on the authority of Piria, *Traité de Chimie Organique*, tome iii. 472. Gerhardt calls it Naphthionic acid and Sulpho-naphtalidamic acid. His formula is $C^{20}H^9NS^2O^6$; and that of the salts is $C^{20}H^8MNS^2O^6$. These formulæ agree precisely with those which he gives for the thionaphtamates. We give, however, some sort of reason for the isomerism which is found here, if we ascribe to one set of salts the formulæ given at Nos. 329 and 330, and to the other set those given at Nos. 337 and 338. It is favourable to this suggestion, that the salts which I have formulated as hyposulphates are much more difficult of decomposition than those which I have described as sulphites. This power of withstanding the decomposing action of reagents is characteristic of the hyposulphates generally.

339. $ZH^2Zn; S^2O^3 + ZH^2H$. Zincam sulphenite, cum amida hydra.

Gmelin calls this salt the Ammonio-hyposulphate of zinc-oxide $= 2NH^3 + ZnO,S^2O^5$.

340. $ZH^2Ni; S^2O^3 + 2ZH^2H$. Niccolousam sulphenite cum amida hydra.

Gmelin's name and formula: Ammonio-hyposulphate of nickel-oxide $= 3NH^3 + NiO,S^2O^5$.

Hyposulphites with Vice-Ammons and Vice-Amids.

341. $ZH,C^6H^5; SO + HSO$. Phenylac sulphate cum hydra sulphate.
342. $ZH,C^6H^5; SO + AgSO$. Phenylac sulphate cum argenta sulphate.
343. $ZH,C^6H^5; SO + ClSO$. Phenylac sulphate cum chlora sulphate.
344. $(ZH^2Zn)^2; S^4O^3$. Zincamen sulphonite.

Usual Names and Formulæ.

341. $ZH,C^6H^5; SO + HSO$. Phenylac sulphate cum hydra sulphate.

Sulphophenylamide, or azoture of sulphophenyle and of hydrogen $= C^6H^7NSO^2$ $= N\begin{cases} C^6H^5SO^2 \\ H \\ H \end{cases}$ *Gerhardt.*

342. $ZH,C^6H^5; SO + AgSO$. Phenylac sulphate cum argenta sulphate.

Azoture of sulpho-phenyle, of silver, and of hydrogen $= C^6H^6NSO^2$ $= N\begin{cases} C^6H^5SO^2 \\ Ag \\ H \end{cases}$ *Gerhardt.*

See No. 325.

343. $ZH,C^6H^5; SO + ClSO$. Phenylac sulphate cum chlora sulphate

Chloride of sulpho-phenyle $= C^{12}H^5S^2O^4Cl$, *Gerhardt.*

These three salts may also be formulated thus:

341. $H; ZH,C^6H^5; (SO)^2$ . . Hydra phenylac bisulphate.
342. $Ag; ZH,C^6H^5; (SO)^2$ . . Argenta phenylac bisulphate.
343. $Cl; ZH,C^6H^5; (SO)^2$ . . Chlora phenylac bisulphate.

344. $(ZH^2Zn)^2; S^4O^3$ . . . . Zincamen sulphonite.

Ammonio-hyposulphite of zinc-oxide $= NH^3 + ZnO,S^2O^2$, *Gmelin.*

Sulphenetes containing Vice-Amids.

345. $\left\{\begin{matrix} ZH,C^6H^5;\ S^2O^2 \\ C^6H^5;\ S^2O^2 \end{matrix}\right\}$ . . Phenylac sulphenete cum phenyla sulphenete.

Gerhardt's name and formula for this salt are—

Azoture of disulphophenyle and of hydrogen $= N\left\{\begin{matrix} C^6H^5SO^2 \\ C^6H^5SO^2 \\ H \end{matrix}\right.$

This salt is procured from No. 342 by a reaction which I have described at page 171.

The Cyanides.

The constitution of cyanogen and the cyanides has been already discussed, first in the investigation of the "sesquioxides," at pages 38 to 43, and secondly in the article on the "nitriles," at pages 217 to 221. A third discussion will be found in the inquiry into the nature of the salts of "aniline," beginning with No. 62 in that series, and another in the article on "Urea." There remain only a few particulars which require illustration under this head, the most important of which is, perhaps, nomenclature.

SINGLE CYANIDES.

346.	HCy	Hydra cyana.
347.	KCy	Potassa cyana.
348.	$AgCy$	Argenta cyana.
349.	$FeCy$	Ferrous cyana.
350.	$FecCy$	Ferric cyana.
351.	$AuCy$	Aurous cyana.
352.	$AucCy$	Auric cyana.
353.	ZH^4,Cy	Ammona cyana.
354.	ZH^2,Cy	Amida cyana.
355.	ZH^3Pt,Cy	Platousam cyana.
356.	$ZH^2(C^7H^5)^2,Cy$	Benzylem cyana.
357.	AsC^2H^6,Cy	Cacodyla cyana.
358.	CH^3,Cy	Methyla cyana.
359.	$ZH,CH^3;\ Cy$	Methylac cyana.
360.	C^5H^{11},Cy	Amyla cyana.
361.	$ZH,C^5H^{11};\ Cy$	Amylac cyana.
362.	C^6H^5,Cy	Phenyla cyana.
363.	$ZH,C^6H^5;\ Cy$	Phenylac cyana.

364.	$ZH,C^7H^7;Cy$	Toluenylac cyana.
365.	$Z(C^2H^5)^2;Cy$	Ethylec cyana.
366.	$Z,C^5H^{11},C^6H^5;Cy$	Amylic-phenylac cyana.

DOUBLE CYANIDES.

367.	$HFecCy^2$	Hydra ferric cyanen.
368.	$KFecCy^2$	Potassa ferric cyanen.
369.	$HAgCy^2$	Hydra argenta cyanen.
370.	$KAgCy^2$	Potassa argenta cyanen.
371.	$HCocCy^2$	Hydra cobaltic cyanen.
372.	$AgCocCy^2$	Argenta cobaltic cyanen.
373.	$HCrcCy^2$	Hydra chromic cyanen.
374.	$FeFecCy^2$	Ferrous ferric cyanen.
375.	$\left\{\begin{matrix}ZH^3,C^7H^7;Cy\\ZH,C^7H^7;Cy\end{matrix}\right\}$	Toluenylam toluenylac cyanen.
376.	$\left\{\begin{matrix}ZH^3,C^9H^{11};Cy\\ZH,C^9H^{11};Cy\end{matrix}\right\}$	Cumenylam cumenylac cyanen.
377.	$\left\{\begin{matrix}ZH^3,C^6H^5;Cy\\ZH,C^6H^5;Cy\end{matrix}\right\}$	Phenylam phenylac cyanen.

TRIPLE CYANIDES.

378.	$HHFeCy^3$	Hydren ferrous cyanine.
379.	$KKFeCy^3$	Potassen ferrous cyanine.
380.	$FecFecFeCy^3$	Ferrenic ferrous cyanine.
381.	$CuCuFeCy^3$	Cuprenous ferrous cyanine.
382.	$CucCucFeCy^3$	Cuprenic ferrous cyanine.
383.	C^2H^5,C^2H^5,Fe,Cy^3	Ethylen ferrous cyanine.
384.	$ZnZnBaCy^3$	Zincen baryta cyanine.

FOURFOLD CYANIDES.

385.	$FeFec^3Cy^4$	Ferrous ferrinic cyanone.
386.	$KNaFec^2Cy^4$	Potassa natra ferrenic cyanone.
387.	$CuAg^3Cy^4$	Cuprous argentine cyanone.
388.	$KAuc^3Cy^4$	Potassa aurinic cyanone.

CYANIDES IN DOUBLE SALTS.

389.	$\left\{\begin{matrix}ZH,C^6H^5;Cy\\ZH,C^6H^5;H\end{matrix}\right\}$	Phenylac cyana cum phenylac hydra.
390.	$\left\{\begin{matrix}ZH,C^7H^7;Cy\\ZH,C^7H^7;H\end{matrix}\right\}$	Toluenylac cyana cum toluenylac hydra.
391.	$\left\{\begin{matrix}ZH,C^{10}H^7;Cy\\ZH,C^{10}H^7;H\end{matrix}\right\}$	Naphtylac cyana cum naphtylac hydra.

392. $\left\{\begin{matrix} ZH,C^6H^4Cl; Cy \\ ZH,C^6H^4Cl; H \end{matrix}\right\}$ Chloric-phenylac cyana cum chloric-phenylac hydra.

393. $\left\{\begin{matrix} ZH\ ,C^6H^5; Cy \\ ZH^3,C^6H^5; Cl \end{matrix}\right\}$ Phenylac cyana cum phenylam chlora.

394. $\left\{\begin{matrix} ZH\ ,C^7H^7; Cy \\ ZH^3,C^7H^7; Cl \end{matrix}\right\}$ Toluenylac cyana cum toluenylam chlora.

395. $\left\{\begin{matrix} ZH\ ,C^{10}H^7; Cy \\ ZH^3,C^{10}H^7; Cl \end{matrix}\right\}$ Naphtylac cyana cum napthtylac chlora.

USUAL NAMES AND FORMULÆ OF THE CYANIDES.

SINGLE CYANIDES.—346, Hydrocyanic acid; prussic acid = C^2NH = HCy, *Gmelin.* 347, Cyanide of potassium = C^2NK, *Gmelin.* 348, Cyanide of silver = AgCy, *Gmelin.* 349, Protocyanide of iron; ferrous cyanide; ferrocyaneisen; eisencyanur = $C^6N^3Fe^3$ or FeCy, *Gmelin.* 350, Sesquicyanide of iron; ferric cyanide; eisencyanid = $C^6N^3Fe^2$ = Fe^2Cy^3, *Gmelin.* See page 39 in this work. 351, Protocyanide of gold; aurous cyanide = AuCy, *Gmelin.* 352, Tercyanide of gold; auric cyanide = $AuCy^3$, *Gmelin.* 353, Cyanide of ammonium; hydrocyanate of ammonia = NH^4Cy = NH^3,HCy = $C^2N(NH^4)$, *Gmelin.* 354, Cyanamide, or azoture of cyanogen and hydrogen = CH^2N^2 = N(CN,H,H), *Gerhardt.* 355, see Platinum, 49]. 356, Unnamed substance = $C^{30}H^{12}N^2$, *Robson, Quarterly Journal Chemical Society*, iv. 228; who supposed it to be benzhydramide (see No. 200). 357, Cyanide of cacodyle = C^6NAsH^6 = C^4ArH^3,C^2NH, *Gmelin.* 358, Acetonitrile = $C^2H^3C^2N$; cyanide of methyl, *Hofmann.* 359, Methyl-cyanamide, or cyanic methylamide = $C^2H^4N^2$ = $N(CH^3,Cy,H)$, *Gerhardt.* 360, Cyanide of amyle; capronitrile; cyanhydramilic ether; cyanmylafer = $C^{12}NH^{11}$ = $C^{10}H^{10},C^2NH$, *Gmelin.* 361, Amyl-cyanamide, or cyanic amylamide = $C^6H^{11}N^2$ = $N(C^5H^{11},Cy,H)$, *Gerhardt.* 362, Benzonitrile; cyanide of phenyle = $C^{14}H^5N$, *Gerhardt.* 363, Phenyl-cyanamide; cyananilide = $C^7H^6N^2$ = $N(C^6H^5,Cy,H)$, *Gerhardt.* See Aniline, 62]. 364, Toluyl-cyanamide = $C^8H^8N^2$ = $N(C^7H^7,Cy,H)$, *Gerhardt.* 365, Diethyl-cyanamide = $C^5H^{10}N^2$ = $N(C^2H^5,C^2H^5,Cy)$, *Gerhardt.* 366, see Aniline, No. 83].

DOUBLE CYANIDES.—367, Hydroferricyanic acid; ferriprussic acid; red ferroprussic acid; ter-hydrocyanate of ferric oxide = $C^6N^3H^3,C^6N^3Fe^2$ = $3HCy,Fe^2Cy^3$, *Gmelin.* 368, Ferricyanide of potassium; red ferrocyanide of potassium; red prussiate of potash; red ferroprussiate of potash = $3KCy,Fe^2Cy^3$ = $C^6N^3K^3,C^6N^3Fe^2$, *Gmelin.* See page 40 of this work. 369, Argentoprussic acid = HCy,AgCy, *Gmelin.* 370, Argentocyanide of potassium = KCy,AgCy, *Gmelin.* 371, Hydrocobaltid cyanic acid = $C^6N^3H^3,C^6N^3Co^2$ = $3HCy,Co^2Cy^3$, *Gmelin.* 372, Cobaltidcyanide of silver = $C^6N^3Ag^3,C^6N^3Co^2$ = $3AgCy,Co^2Cy^3$, *Gmelin.* 373, Hydrochromidcyanic acid = $3HCy,Cr^2Cy^3$ = $C^6N^3H^3,C^6N^3Cr^2$, *Gmelin.*

374, Prussian blue; Turnbull's Prussian blue = $C^6N^3Fe^3,C^6N^3Fe^3$ = $3FeCy,Fe^2Cy^3$, *Gmelin.* See page 41. 375, Cyanotoluidine = $Cy,C^{14}H^9N$, *Hofmann.* 376, Cyanocumidine = $Cy,C^{18}H^{13}N$, *Hofmann.* 377, Cyaniline = $Cy,C^{12}H^7N$. See Aniline, 84], where the reason for doubling the formulæ of the salts 375, 376, and 377, is given.

Triple Cyanides.—378, Hydroferrocyanic acid; ferroprussic acid; ferruretted chyazic acid = $2HCy,FeCy$ = $C^6N^3FeH^2$, *Gmelin.* 379, Yellow prussiate of potash; ferrocyanide of potassium; ferroprussiate of potash = K^2FeCy^3 = $C^6N^3FeK^2$, *Gmelin.* 380, Ordinary Prussian blue (not Turnbull's; see No. 374, and refer to page 40) = $C^6N^3Fe^3$, $2C^6N^3Fe^2$ = $3FeCy,2Fe^2Cy^3$, *Gmelin.* 381, Cuprous ferrocyanide = Cu^4FeCy^3, *Gmelin.* 382, Cupric ferrocyanide = Cu^2FeCy^3 = $C^6N^3FeCu^2$, *Gmelin.* 383, Ferrocyanide of ethyl = $(C^4H^5)^2FeCy^3$ = $C^6N^3FeAe^2$, *Gmelin.* 384, Cyanide of zinc and barium = $BaCy,2ZnCy$, *Gmelin.*

Fourfold Cyanides.—385, Prussian green; green cyanide of iron = $C^6N^3Fe^3,3C^6N^3Fe^2$, *Gmelin.* 386, Double salt, red prussiate of potash and soda = $K^3Na^3Fe^4N^{12}C^{12}$ = $C^3N^3feK\frac{1}{2}Na\frac{1}{2}$, *Laurent.* 387, Cuprocyanide of silver = $3AgCy,Cu^2Cy$, *Gmelin.* 388, Auridcyanide of potassium = $KCy,AuCy^3$, *Gmelin.*

Cyanides in Double Salts.—389, Melaniline, see Aniline, 63]. 390, Metoluidine = $C^{30}H^{17}N^3$, *W. Wilson.* 391, Menaphthalamine = $C^{42}H^{17}N^3$, *Hofmann.*

These three compounds have evidently a corresponding structure. Hence, the criticism given in the note to Aniline, 63] may be held to apply to the whole of them. 392, see Aniline, 71]. 393, see Aniline, 64]. 394, Hydrochlorate of metoluidine = $C^{30}H^{17}N^3,HCl$. 395, Hydrochlorate of menaphthalamine = $C^{42}H^{17}N^3HCl$, *Hofmann.*

The theory, according to which I have formulated and named the cyanides, does not require the assistance of any hypothetical secondary radicals, such as cobalticyanogen, chromicyanogen, platinocyanogen, ferrocyanogen, ferricyanogen, &c. But it requires the acceptance of the theory of basylous and basylic atoms, as it is described at pages 32 to 43. The ordinary theory, even with the aid of numerous secondary radicals, provides the cyanides with formulæ which are much more complicated than those that are provided by the radical theory.

The Sulphocyanides.

396.	H,Cy,S^2	Hydra cyana sulphene.
397.	K,Cy,S^2	Potassa cyana sulphene.
398.	ZH^4,Cy,S^2	Ammona cyana sulphene.
399.	Cu,Cy,S^2	Cuprous cyana sulphene.
400.	Cuc,Cy,S^2	Cupric cyana sulphene.
401.	Hg,Cy,S^2	Mercurous cyana sulphene.
402.	Pt,Cy,S^2	Platous cyana sulphene.
403.	Bic,Cy,S^2	Bismic cyana sulphene.
404.	C^2H^5,Cy,S^2	Ethyla cyana sulphene.
405.	CH^3,Cy,S^2	Methyla cyana sulphene.
406.	ZH^3Zn,Cy,S^2	Zincam cyana sulphene.
407.	ZH^3Pt,Cy,S^2	Platousam cyana sulphene.
408.	$ZH^3,C^6H^5;\ Cy;\ S^2$	Phenylam cyana sulphene.
409.	$ZH^2(C^6H^5)^2,Cy,S^2$	Phenylem cyana sulphene.
410.	$ZH^3,C^3H^5;\ Cy;\ S^2$	Allylam cyana sulphene.
411.	$Cu,Cuc,Cy^2\ S^4$	Cuprous cupric cyanen sulphone.
412.	K,Ag,Cy^2,S^4	Potassa argenta cyanen sulphone.
413.	H,Pt,Cy^2S^4	Hydra platous cyanen sulphone.
414.	K,Pt,Cy^2,S^4	Potassa platous cyanen sulphone.
415.	Ag,Pt,Cy^2,S^4	Argenta platous cyanen sulphone.
416.	ZH^4,Cy^3,S^4	Ammona cyanine sulphone.
417.	ZH^3K,Cy^3,S^4	Potassam cyanine sulphone.
418.	ZH^3Ag,Cy^3,S^4	Argentam cyanine sulphone.
419.	K,Hg^2,Cy^3,S^6	Potassa merenous cyanine sulphade.
420.	H,Ptc^2,Cy^3,S^6	Hydra platenic cyanine sulphade.
421.	ZH^4,Ptc^2,Cy^3,S^6	Ammona platenic cyanine sulphade.
422.	K,Ptc^2,Cy^4,S^6	Potassa platenic cyanine sulphade.
423.	Ag,Ptc^2,Cy^3,S^6	Argenta platenic cyanine sulphade.
424.	Hg,Ptc^2,Cy^3,S^6	Mercurous platenic cyanine sulphade.
425.	Fe,Ptc^2,Cy^3,S^6	Ferrous platenic cyanine sulphade.
426.	H^2,Cy,S^3	Hydren cyana sulphine.
427.	H,ZH^4,Cy,S^3	Hydra ammona cyana sulphine.
428.	H,Cy,S^3	Hydra cyana sulphine.

USUAL NAMES AND FORMULÆ.

$$396.\ \begin{cases} H,Cy,S^2 = \text{Hydra cyana sulphene.} \\ HS + CyS = \text{Hydra sulpha cum cyana sulpha.} \end{cases}$$

This is the compound commonly called hydro-sulpho-cyanic acid, and which is regarded by most chemists as a compound of hydrogen with a hypothetical radical called sulpho-cyanogen $H + CyS^2$. I do not believe in the existence of sulpho-cyanogen; and I consider these compounds to be double sulphides, containing sulphide of cyanogen in combination with a sulphide of another radical = $H'S + CyS$.

397, Sulpho-cyanide of potassium = K,NC^2S^2 or K,Scy, *Miller.* = C^2NK,S^2, *Gmelin.* 398, Sulpho-cyanide of ammonium = NH^3,C^2NHS^2, *Gmelin.* 399, Cuprous sulpho-cyanide = C^2NCu^2,S^2, *Gmelin.* 400, Cupric sulpho-cyanide = C^2NCuS^2, *Gmelin.* See No. 411. 401, Mercurous sulpho-cyanide = $C^2NHg^2S^2$, *Gmelin.* 402, Protosulpho-cyanide of platinum = $PtCyS^2$, *Buckton.* 403, Sulpho-cyanide of bismuth = $C^6N^3BiS^6$. *Gmelin.* The triple quantities of cyanogen and sulphur are to accommodate the triple (basylous) atom of bismuth. Of course, if the basylic atom is accepted, the triplication of the formula is needless. 404, Sulpho-cyanide of ethyl, or hydro-sulpho-cyanic ether = $C^6H^5NS^2 = C^4H^4,C^2NHS^2 = C^4H^5S,C^2NS$, *Gmelin.* 405, Sulpho-cyanide of methyl = $C^2H^3S,C^2NS = C^2H^3,C^2NS^2$, *Gmelin.* 406, Ammonia-sulpho-cyanide of zinc = NH^3,C^2NZnS^2, *Gmelin.* Similar salts are formed by ammonams containing cadmium, copper, &c. 407, Sulpho-cyanide of platos-ammonium = PtH^3NCyS^2, *Buckton.* 408, Hydro-sulpho-cyanate of aniline = $C^{12}H^7N,HC^2NS^2$, *Hofmann.* 409, Sulpho-carbanilide, or anilo-sulpho-carbamide = $C^{12}H^6N,CS$, *Hofmann.* Diphenyl-sulpho-carbamide, or diazoture of diphenyle and of sulpho-carbonyle

$$= N^2\left\{\begin{array}{l} CS \\ (C^6H^5)^2, \textit{ Gerhardt.} \\ H^2 \end{array}\right.$$

410, Thiosinamine, or sulphuretted diallyl-urea = $C^4H^8N^2S$

$$= N^2\left\{\begin{array}{l} CS \\ C^3H^5, \textit{ Gerhardt.} \\ H^3 \end{array}\right.$$

411. Cuproso-cupric sulpho-cyanide, or Kupfer-rhodanur-rhodanid = $C^4N^2Cu^3S^4 = C^2NCu^2S^2,C^2NCuS^2$, *Gmelin.* 412, Sulpho-cyanide of silver and potassium = C^2NKS^2,C^2NAgS^2, *Gmelin.*

413, Hydro-platino-bisulpho-cyanic acid = $HPt\,2(CyS^2)$, *Buckton.* 414, Platino-bisulpho-cyanide of potassium = $KPtC^4N^2S^4$ or $KPt\,2(CyS^2)$, *Buckton.* 415, Platino-bisulpho-cyanide of silver = $AgPt\,2(CyS^2)$, *Buckton.* 416, Sulpho-mellonic acid = $C^6H^4N^4S^2$

$$= \begin{array}{l} S^2 \\ N \end{array}\left\{\begin{array}{l} Cy^3 \\ H^4 \end{array}\right. = \left\{\begin{array}{l} 2S\left\{\begin{array}{l} Cy \\ H \end{array}\right. \\ N\left\{\begin{array}{l} Cy, \\ H \\ H \end{array}\right. \end{array}\right.$$

Gerhardt. In other places he writes the formulæ = $C^6H^4N^4S^4$ = $(NCyH^2,2CyHS^2)$. 417 and 418 are sulpho-mellonates or salts of the "acid," No. 416. If I reckon this acid as a salt of ammonium (the "acids" of organic chemists are frequently neutral salts of ammonium), then the salts 417 and 418 differ from the acid 416, in containing ammonams instead of normal ammonium. In 417 it is potassam ZH^3K; in 418 it is argentam ZH^3Ag: but other salts are known which contain the radicals ZH^3Na,ZH^3Ba,ZH^3Sr, ZH^3Ca,ZH^3Mg, &c. 419, Sulpho-cyanide of mercury and potassium $= C^2NKS^2,2C^2NHgS^2$, *Gmelin.* 420, Hydroplatino-tersulphocyanic acid $= H,Pt\,3CyS^2$, *Buckton.* 421, Platino-tersulphocyanide of ammonium $= NH^4,Pt\,3CyS^2$, *Buckton.* 422, Platino-tersulphocyanide of potassium $= KPtC^6N^3S^6$, or $KPt\,3CyS^2$, *Buckton.* 423, Platino-tersulphocyanide of silver $= Ag,Pt\,3(CyS^2)$, *Buckton.* 424, Subplatino-tersulphocyanide of mercury $= Hg^2Pt\,3(CyS^2)$, *Buckton.* 425, Platino-tersulphocyanide of iron $= FePt\,3CyS^2$, *Buckton.*

426, H^2CyS^3, or according to the analytical formula $HS + HS + CyS$. This compound seems to throw discredit upon the theory which assumes the existence of sulphocyanogen; for we have here a combination of three sulphides, which view is corroborated by the constitution of the next salt in the list, No. 427, which contains $HS + ZH^4S + CyS$. The salt No. 426 has given theoretical chemists a great deal of trouble. Gmelin calls it Hydrothio-sulphoprussic acid, and gives it all these formulæ: $C^2NH^2S^3 = C^2NH,S^2HS = C^2AdS,S^2 = C^2AdS^2 + 2CS^2$. He also quotes the following: C^2NHS^2,HS, *Zeise.* $C^2NHS^2 + HS$, *Berzelius*, in which formula C^2NH represents a peculiar radical, *Urene.* $C^2AdS.S^2$, *Laurent.*

427, Hydrothio-sulphoprussiate of ammonia, or hydrothio-cyanide of ammonium $= NH^3,C^2NH^2S^3 = C^2NH(NH^4)S^3$, *Gmelin.* See preceding note.

428, Hydropersulphocyanic acid, or sulphuretted hydrosulphocyanic acid $= C^2NHS^3 = C^2NHS^2,S = H,C^2NS^3 = C^4N^2H^2,S^6 = C^2NAdS^2 + 2CS^2$, *Gmelin.* Here is another compound which, in the relations of Cy to S, does not agree with the sulphocyanogen theory. This, however, is one of those compounds with multiple atoms of sulphur, the nature of which I do not understand.

The Cyanates.

429.	H, CyO	. . .	Hydra cyanate.
430.	Ag, CyO	. . .	Argenta cyanate.
431.	CH^3, CyO	. . .	Methyla cyanate.
432.	C^2H^5, CyO	. . .	Ethyla cyanate.
433.	C^5H^{11}, CyO	. . .	Amyla cyanate.
434.	C^6H^5, CyO	. . .	Phenyla cyanate.
435.	ZH^4, CyO	. . .	Ammona cyanate.

The cyanates are salts that are formed on the model of water, M^r,CyO, or $\left.\begin{matrix}M^r\\Cy\end{matrix}\right\}O$, where M^r signifies one replaceable positive radical, $O = 16$, and $Cy = (C = 12$ and $N = 14)$. They are consequently equal to simple cyanides plus one atom of oxygen.

Usual Names and Formulæ.

429. Cyanic acid $= CyO,HO$, *Gerhardt*, or HO,C^2NO, *Miller*.

430. Cyanide of silver, or argentic carbonimide $= N\left\{\begin{matrix}CO\\Ag\end{matrix}\right.$, *Gerhardt*.

431. Methyl-cyanic ether $= C^2H^3O,C^2NO$, *Miller*.

Cyanate of methyle; methylcarbonimide; or azoture of methyle and of carbonyle $= C(CH^3)NO = N\left\{\begin{matrix}CO\\CH^3\end{matrix}\right.$;

also $O\left\{\begin{matrix}CH^3\\Cy\end{matrix}\right.$, *Gerhardt*.

432. Cyanic ether $= C^4H^5O,C^2NO$, *Miller*.

Cyanate of ethyle; ethylcarbonimide; or azoture of ethyle and of carbonyle $= C(C^2H^5)NO = N\left\{\begin{matrix}CO\\C^2H^5\end{matrix}\right.$;

also $O\left\{\begin{matrix}C^2H^5\\Cy\end{matrix}\right.$, *Gerhardt*.

433. Amyl-cyanic ether $= C^{10}H^{11}O,C^2NO$, *Miller*.

Cyanate of amyle $= C^6H^{11}NO = O\left\{\begin{matrix}C^5H^{11}\\Cy\end{matrix}\right.$, *Gerhardt*.

434. Anilocyanic acid, *Hofmann*. See Aniline, 95].

Cyanate of phenyle; phenylcarbonimide; or azoture of phenyle and of carbonyle $= C(C^6H^5)NO = N\left\{\begin{matrix}CO\\C^6H^5\end{matrix}\right.$ —*Gerhardt*.

435. Cyanate of ammonia. A full investigation of this compound is given under the head of "The Urea Theory."

A variety of complex cyanates are described under "Aniline," Nos. 89] to 99].

The Nitrates.

The formula usually given to a Nitrate is MO,NO^5, where $O = 8$. Doubling the atomic weight of the oxygen, these proportions give us *analytically*, $MO + NOO$; and *synoptically*, M,NO^3.

As the nitrates have not formed the subject of conflicting discussion among chemists, in consequence of the scarcity of their acid salts and double salts, I shall trouble the reader with only a few notes and queries respecting them.

436. H,NO^3 = Hydra nitrite. Usual name, hydrated nitric acid = HO,NO^5.

437. K,NO^3 = Potassa nitrite. Usual name, nitrate of potash = KO,NO^5. The change in the name from nitrate to nitrite is rather unlucky, as there is, on the ordinary theory, another class of salts called nitrites; but the change is unavoidable in carrying out a systematic nomenclature.

438. $PbNO^3$. Plumba nitrite. [= Neutral nitrate of lead.]

$$439.\ \left\{\begin{array}{c} PbNO^3 + PbPbO \\ \text{or } Pb^3NO^4 \end{array}\right\} \text{Plumbine nitrote.}$$

$$440.\ \left\{\begin{array}{c} PbNO^3 + PbHO \\ \text{or } Pb^2H,NO^4 \end{array}\right\} \text{Plumben hydra nitrote.}$$

$$441.\ \left\{\begin{array}{c} (PbNO^3 + PbPbO) + PbNO^3 \\ \text{or } = Pb^4N^2O^7 \end{array}\right\} \text{Plumbone nitreneze.}$$

These sub-salts correspond in their construction with the three varieties of phosphates. They have not the permanency nor the properties of the phosphates; but they resemble them in their proximate constitution —in their atomic structure.

	Phosphates.	Nitrates.
Monobasic . .	$Pb\,P\,O^3$	$Pb\,N\,O^3$
Terbasic . . .	$Pb^3P\,O^4$	$Pb^3N\,O^4$
	$Pb^2HP\,O^4$	$Pb^2HN\,O^4$
Bibasic . . .	$Pb^4P^2O^7$	$Pb^4N^2O^7$

See the Article on the Constitution of the Phosphates, pp. 138–142.

442. CH^3,NO^3 . . . . Methyla nitrite.
443. $ZH^3,CH^3; NO^3$ . . Methylam nitrite.
444. C^2H^5,NO^3 . . . . Ethyla nitrite.

445. $Z(C^2H^5)^4 ; NO^3$ . . Ethylom nitrite.
446. C^5H^{11},NO^3 . . . . Amyla nitrite.
447. $Z(C^5H^{11})^4 ; NO^3$. Amylom nitrite.
448. C^6H^5,NO^3 . . . . Phenyla nitrite.
449. $ZH^3,C^6H^5 ; NO^3$. Phenylam nitrite.

The salts 442 to 449 are examples of nitrates having as basic radical, either a compound radical, or a vice-ammonium containing one or more atoms of a compound radical.

USUAL NAMES.—442, Methylic nitrate. 443, Nitrate of methylamine. 444, Nitrate of ethyle. 445, Nitrate of tetrethylammonium. 446, Nitrate of amyle. 447, Nitrate of tetramylammonium. 448, Nitrophenic acid, or nitrophenole. 449, Nitrate of aniline. As these salts are cited here simply as examples of nitrates, I say nothing about their bases, which are explained in other sections.

450. $ZH^2,C^6H^5 ; CyO + H\ NO^3$ Phenylam cyanate cum hydra nitrite.
451. $ZH^2,C^6H^5 ; CyO + AgNO^3$ Phenylam cyanate cum argenta nitrite.

USUAL NAMES.—450, Nitrate of carbanilamide. 451, Nitrate of silveroxide carbanilamide. Cited as examples of nitrates in combination with salts containing a different acid.

ARE THE FOLLOWING SALTS TO BE CONSIDERED AS DOUBLE NITRATES?

452. $C^7H,NO^3 + H,\ NO^3$ Chrysyla hydra binitrite.
453. $C^7H,NO^3 + K,\ NO^3$ Chrysyla potassa binitrite.
454. $C^7H,NO^3 + Pb,\ NO^3$ Chrysala plumba binitrite.
455. $C^7H,NO^3 + Pb^2H,\ NO^4$ Chrysyla nitrite cum plumben hydra nitrote.
456. $C^7H,NO^3 + ZH^4,\ NO^3$ Chrysyla ammona binitrite.
457. $C^7H,NO^3 + ZH^2,\ NO^2$ Chrysyla nitrite cum amida nitrete.
458. $C^7H,NO^3 + ZH^3Ba,NO^3$ Chrysyla barytam binitrite.

USUAL NAMES.—452, Chrysammic acid = $C^{14}H^2(NO^4)^2O^4$. 453, Chrysammate of potash = $C^{14}HK(NO^4)^2O^4$. 454, Chrysammate of lead = $C^{14}HP(NO^4)^2O^4$. 455, Sub-chrysammate of lead = $C^{14}HPb(NO^4)^2O^4$, PbO,HO. 456, Chrysamidic acid = $C^{14}H^5(NO^4)^2NO^4$. 457, Chrysamide = $C^{14}H^3(NO^4)^2NO^2$. 458, Chrysamidate of barytes = $C^{14}H^4Ba(NO^4)^2NO^4$. These names and formulæ are by Gerhardt.

The salt No. 456 appears to be the neutral salt of ammonia corresponding to the acid, No. 452, and to the potash salt, No. 453; and the existence of the corresponding amide, No. 457, seems to prove the truth of this idea. But it was found that the salt, No. 456, could exchange H^1 for Ba^1, and produce the salt No. 458; and for this reason alone, the neutral salt, No. 456, was called an "acid." This muddle, as in many similar cases, has arisen from a misconception of the character of the radical (ZH^3Ba). These metallic vice-ammoniums have not hitherto been recognised by chemists; but I trust that the evidence which I shall bring together in the articles on Indigo and Platinum will prove to chemists their existence and importance. See also pages 137 and 193.

459. $C^2H^5; Bi; (NO^3)^2$ or $C^2H^5,NO^3 + BiNO^3$ Ethyla bismous binitrite.

Nitrate of bismuthethyle = $C^4H^5Bi,O^2,2NO^5$, *Gerhardt*.

460. $\left\{\begin{matrix} ZH, C^6H^5; NO^3 \\ ZAg,C^6H^5; NO^3 \end{matrix}\right\}$ Phenylac nitrite cum argentic-phenylac nitrite.

Binitrodiphenamate of silver = $C^{24}H^{11}Ag(NO^4)^2N^2O^4$, *Gerhardt*.

There are various salts having the same formula as 460, with Ag exchanged for another radical.

ANHYDROUS NITRIC ACID.—The anhydrous nitric acid is derived from the decomposition of two atoms of the hydrated acid, thus:

$$\left.\begin{matrix} HO,NOO \\ HO,NOO \end{matrix}\right\} = \left\{\begin{matrix} HO & & NOO \\ H & + & O,NOO \end{matrix}\right\} = H,HO + N,NO^5.$$

The Nitrites.

The terms nitrous acid, hyponitrous acid, and hyponitric acid are used by chemists with a perplexing vagueness. There is but one kind of salt, though we have three kinds of name for it. Nitrites agree with Nitrates in having the same positive and negative radicals, but Nitrites have only two-thirds of the quantity of oxygen which is necessary to constitute Nitrates. If Nitrates have the formula HO,NO^5, Nitrites require the formula HO,NO^3. According to the radical theory, these salts are distinguished thus:—

Nitrate of potash = KNO^3 = Potassa nitrite.
Nitrite of potash = KNO^2 = Potassa nitrete.

The following examples of Nitrites nearly all contain debateable "bases," so that the usual formulæ of the salts differ entirely from those that are given here. I refer the reader, in those cases which are important, to the sections in which the evidence respecting the nature of the bases is investigated.

461. $ZH,C^2H^5; NO^2$ . . Ethylac nitrete.
462. $ZZn,C^2H^5; NO^2$ . . Zinc-ethylac nitrete.

463.	$ZZn^2(C^2H^5)^2; NO^2$	Zincen-ethylem nitrete.
464.	$ZH,CH^3; NO^2$	Methylac nitrete.
465.	$ZZn,CH^3; NO^2$	Zinc-methylac nitrete.
466.	$ZZn^2(CH^3)^2; NO^2$	Zincen-methylem nitrete.
467.	$ZH,C^7H^7; NO^2$	Toluenylac nitrete.
468.	$ZH,C^{10}H^7; NO^2$	Naphtylac nitrete.
469.	$ZH,C^6H^5; NO^2$	Phenylac nitrete.
470.	$\left\{\begin{matrix} ZH,C^6H^5; NO^2 \\ H \quad ; CyO \end{matrix}\right\}$	Phenylac nitrete cum hydra cyanate.
471.	$Z,C^2H^5,C^6H^5; NO^2$	Ethylic-phenylac nitrete.
472.	$ZH^3,C^7H^5; NO^2$	Benzylam nitrete.
473.	$\left\{\begin{matrix} ZH^3,C^7H^5; NO^2 \\ (H; Cl)^2 \end{matrix}\right\}$	Benzylam nitrete bis hydra chlora.
474.	$\left\{\begin{matrix} ZH^3,C^7H^5; NO^2 \\ (H; SO^2)^2 \end{matrix}\right\}$	Benzylam nitrete bis hydra sulphete.

USUAL NAMES AND FORMULÆ:—Nos. 461 to 466. Examples of Professor Frankland's Dinitroethylates and Dinitromethylates. See those sections in the article on Conjugated Acids. 467, Nitrotoluidine $= C^{14}H^8(NO^4)N$, *Gerhardt*. 468, Nitronaphtylamine $= C^{20}H^8(NO^4)N$, *Gerhardt*. 469, Nitraniline. See Aniline, No. 54]. 470, Carbamide—nitrocarbanilide. See Aniline, No. 58]. A variety of double salts, containing No. 469 as a constituent, are described in the article "Aniline," between Nos. 54] and 61]. It is important to observe that I consider No. 461 $= ZH,C^2H^5; NO^2$ as the same kind of salt with No. 469 $= ZH,C^6H^5; NO^2$. Upon comparing this view with the theories of Frankland and Hofmann respectively, very curious divergencies in the mode of accounting for facts will be seen. 471, Ethyl-nitraniline

$$= C^{16}H^{10}N^2O^4 = C^{12}\left\{\begin{matrix} H^5 \\ NO^4 \\ C^4H^5 \end{matrix}\right\}N. \textit{ Hofmann.}$$

472, Biamidobenzoic acid $= C^{14}H^4(NH^2)^2O^4$, *Voit*. 473, Hydrochlorate of biamidobenzoic acid $= C^{14}H^4(NH^2)^2O^4,2HCl$, *Voit*. 474, Sulphate of biamidobenzoic acid $= C^{14}H^4(NH^2)^2O^4,S^2H^2O^8$, *Voit*. In Nos. 472 to 474 "it is remarkable that biamidobenzoic acid does not combine with bases, but forms well-crystallized salts with acids, whence the name of acid is not very appropriate for it," *Voit*. See his Memoir, *Quarterly Journal Chemical Society*, ix. 271. It seems to me, that an "acid" with such properties might be conveniently classed with sulphate of potash, which, on these grounds, has an equal right to be called an "acid." The biamidobenzoic acid will be referred to more particularly in another section.

The Oxides and Hydrates of Nitrogen.

The formulæ of the oxides and hydrated oxides of nitrogen are usually written in accordance with the supposition that the atomic weights of their elements are, N = 14, H = 1, O = 8. In this work, the atomic weights of these elements are fixed at N = 14, H = 1, O = 16. These proportions necessarily give entirely new formulæ to the compounds, and it seems proper to give a short general notice of them, to prevent misapprehension.

Oxides.			Corresponding Hydrates.		
475.	NO =	Nitrate.			
476.	NO^2 =	Nitrete.			
477.	N,NO =	Nitra nitrate.	480.	H,NO =	Hydra nitrate.
478.	N,NO^3 =	Nitra nitrite.	481.	H,NO^2 =	Hydra nitrete.
479.	N,NO^5 =	Nitra nitrute.	482.	H,NO^3 =	Hydra nitrite.

According to the radical theory, all the compounds from No. 477 to 482 should be considered as salts.

Usual Names and Formulæ.

475, NO = Nitrate.
Nitric oxide, binoxide of nitrogen, deutoxide of nitrogen = NO^2. Atomic weight, 30; specific gravity of gas, 15; atomic measure, 2. Neutral to test papers.

476, NO^2 = Nitrete.
Peroxide of nitrogen; hyponitric acid; sometimes nitrous acid = NO^4. Atomic weight, 46; specific gravity of gas, 23; atomic measure, 2. Reddens litmus.

477, N,NO = Nitra nitrate.
Nitrous oxide; protoxide of nitrogen; laughing gas = NO. Atomic weight, 44; specific gravity of gas, 22; atomic measure, 2. Neutral to test papers.

478, N,NO^3 = Nitra nitrite.
Nitrous acid; sometimes hyponitrous acid; meaning, of course, the anhydrous acid = NO^3. Atomic weight, 76; specific gravity and atomic measure of the gas not yet determined.

479, N,NO^5 = Nitra nitrute.
Anhydrous nitric acid = NO^5. Atomic weight, 108; specific gravity and atomic measure unknown.

480, H,NO = Hydra nitrate.
Unknown; unrecognised; unnamed.

481, H,NO^2 = Hydra nitrete.

Hydrated nitrous acid = HO,NO^3. Atomic weight, 47. This is the acid which corresponds to the nitrites, Nos. 461 to 474 in this series.

482, H,NO^3 = Hydra nitrite.

Hydrated nitric acid = HO,NO^5. Atomic weight, 63. This is the acid already referred to at No. 436 in this series.

I have included among the hydrates a compound (No. 480) that is not recognised by chemists, but which will, in all probability, be discovered when it is looked for. It is the compound which corresponds in the nitrogen series with the salt HSO (= hydra sulphate or pentathionic acid) in the sulphur series. The corresponding anhydrous compound is known in the nitrogen, though not known in an isolated state in the sulphur series. There seems to be no reason why the hydrated form of the acid should not exist in the nitrogen as well as the sulphur series. The following equation represents a transformation that is, *à priori*, by no means improbable:

$$\left.\begin{array}{l}\text{No. 477} = N,NO \\ \text{Water} = H,HO\end{array}\right\} = \left\{\begin{array}{l}HNO \\ HNO\end{array}\right\} = \begin{array}{c}\text{Two atoms of} \\ \text{No. 480.}\end{array}$$

I am not pleading that this compound HNO really exists. I am only showing that the radical theory indicates its possible existence, which is a sufficient reason to induce us to look for it, especially as it is required to complete a series.

Azotic Radicals in Series.

The next three sections contain the "bases" that are usually called Indigo, Aniline, and Platinum. In these sections I shall show a complete series of the salts of these "bases," which are unquestionably three of the great "difficulties" in theoretical chemistry. I have chosen them as examples because they are difficult; because I wish to show that the Theory and the Nomenclature which I am advocating, do not give way under the pressure of difficulties; and finally, because my conclusions respecting these bases are so different from those of chemists in general, that the results of the investigation may be taken as a fair example of what may be expected from the application of the proposed radical theory to chemistry in general. I have, in regard to these bases, quoted the arguments fully and discussed them freely; so that the reader will find the cases stated ready for his judgment. He will have to answer such questions as these:—Are the Theory and Nomenclature that are proposed for the salts of Indigo better or worse than those of Berzelius? Are those proposed for the salts of Aniline better or worse than those of Hofmann? Are those proposed for the Platinum bases better or worse than those of Gros, and Reiset, and Raewsky, and Gerhardt?

Of course, the consideration of the replies proper to be made to these questions, involves the consideration of the merit of the leading doctrines of the radical theory and of the chemical nomenclature, which, though forming no part of the radical theory, I have grafted upon it.

A peculiarity to which I must direct the reader's attention in reference to these three bases, is, that the salts of indigo, aniline, and platinum, though all salts of vice-ammons or vice-amids, differ in structure from one another essentially. The general character of the indigo salts agrees in no respects with that of the salts of aniline or platinum, and the salts of aniline are throughout quite unlike the salts of platinum. So also the theories which chemists have employed to explain these salts are extremely different from one another, and the various nomenclatures that have been proposed have scarcely any points in common.

But the radical theory and its nomenclature apply with equal facility to the whole of these complicated and diversified salts. The comprehensiveness of the theory, and the flexibility of the nomenclature, satisfy every demand; and these are prime requisites in a theory and nomenclature that pretend to fulfil the requirements of a science which is so eminently expansive and progressive as the science of chemistry.

Indigo.

The principal compound of the Indigo series is INDIGO BLUE, which is represented by the empirical formula C^8H^5NO, where $C = 12$, $H = 1$, $N = 14$, $O = 16$. Gerhardt considered this oxidised compound to be the radical of the indigo series, and he called it *Indyle*. Berzelius thought it expedient to distinguish the compounds of indigo by a variety of radicals, and he accordingly adopted the following:—

$C^{16}H^{3}N$ = Flavinden
$C^{16}H^{4}N$ = Porrinden
$C^{16}H^{5}N$ = Inden.
$C^{16}H^{6}N$ = Isaten.

$C^{32}H^{11}N^{3}$ = Polinden.
$C^{32}H^{12}N^{2}$ = Rosinden.
$C^{32}H^{13}N^{2}$ = Xanthinden.
[In these formulæ $C = 6$.][1]

For these radicals he provided formulæ in which the symbols were written in Greek.

It is proposed, on the present occasion, to adopt, as the radical of the Indigo series, a Hydrocarbon agreeing in composition with the formula C^8H^3, and to call it INDYL. This radical is subject to have part, or the whole, of its hydrogen replaced by chlorine, bromine, and sulphur; and, in this manner, to produce the following Vice-Radicals:—

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[1] In all quotations of ordinary formulæ, it is to be understood that $C = 6$, $O = 8$, $H = 1$, $N = 14$.

$$\text{Vice-Indyls.}\left\{\begin{matrix} C^8H^2Cl & = & \text{Chloric-indyl.} \\ C^8H^2Br & = & \text{Bromic-indyl.} \\ C^8H^2S & = & \text{Sulphic-indyl.} \\ C^8HCl^2 & = & \text{Chlorenic-indyl.} \\ C^8HBr^2 & = & \text{Bromenic-indyl.} \\ C^8HClS & = & \text{Chloric-sulphindyl.} \\ C^8Cl^2S & = & \text{Chlorenic-sulphindyl.} \\ C^8Br^2S & = & \text{Bromenic-sulphindyl.} \end{matrix}\right.$$

The Vice-Radicals that contain chlorine and bromine without sulphur, act like normal Indyl. They have the same saturating capacity, and their salts have the same proportion of oxygen. The sulphic vice-radicals, as usual, take additional oxygen, and form double salts.

The indigo series presents no other peculiar radical than indyl. They all contain either amidogens or ammoniums, and in all of them the radical indyl is found, sometimes as the negative radical, and sometimes as a component of the vice-amid or vice-ammon, which forms the positive radical. The indigo salts are quite regular in all other respects; so that Berzelius's army of Greek radicals may be dismissed as needless supernumeraries.

Section 1.—SALTS IN WHICH INDYL IS THE NEGATIVE RADICAL.

1]. $ZH^2; C^8H^3O$ = Amida indylate.

It is assumed that INDIGO BLUE—or Indigotine—is a salt which contains the radical indyl, acting as an acid radical, in combination with one atom of oxygen, and with normal amidogen acting as a basic radical; which combination requires the following formula and name:

$$ZH^2; C^8H^3O = \text{Amida indylate.}$$

It is no part of the business of this Essay to describe either the properties or preparation of the substances to which allusion is made. I may refer those who wish for detailed information respecting the Indigo Salts, to the following works, in which are described all the compounds that I shall refer to in this article. GMELIN, *Handbuch der Chemie*, Band vi. LIEBIG's *Handwörterbuch der Chemie*, Band iv., several articles written by STRECKER, from which I quote BERZELIUS's names. GERHARDT, *Traité de Chimie Organique*, tome iii. Shorter notices will be found in the Treatises on Organic Chemistry by Professors Gregory and Miller.

$$2].\left\{\begin{matrix} ZH^4; C^8H^3O \\ ZH^2; C^8H^3O \end{matrix}\right\} = \text{Ammona indylate cum amida indylate.}$$

By certain chemical processes, indigo blue can be converted into a substance which is called *Indigogen*, or WHITE INDIGO. The process which effects this change is called "reduction," and the resulting compound is also called *Reduced Indigo.* The act of reduction consists in adding one atom of hydrogen to one atom of blue indigo, and thereby converting

$$ZH^2,C^8H^3O \text{ into } ZH^3,C^8H^3O.$$

This new formula is not in accordance with the amidogen and ammonium theories. H^3 forms neither an amidogen nor an ammonium. It is not therefore immediately evident how the additional atom of hydrogen is connected with the indigo blue, and chemists have given many different explanations of this difficulty. Berzelius even resorted to the expedient of adopting a special radical, Isaten = C^8H^6N to explain it. According to him, indigo white should be called Isaten oxydul.

Nevertheless, what it is difficult to understand of this occurrence in relation to *one* atom of the compound, becomes easy if we regard it as taking place with *two* atoms; for, if two atoms of indigo blue take up two atoms of hydrogen, and produce a compound that agrees with the following formula, we perceive that the difficulty is gone, and that we are looking upon a change that is analogous to many that occur with other compounds of the azotic series:—

$$\text{Indigo white} = \left\{\begin{matrix} ZH^4,C^8H^3O \\ ZH^2,C^8H^3O \end{matrix}\right\} \begin{matrix} \text{Ammona indylate cum amida} \\ \text{indylate.} \end{matrix}$$

According to this view of the transformation, indigo blue is a simple indylate with an amidogen base, and indigo white is a double indylate, with one amidogen base and one ammonium base. In so far as *per centage* relations are in question, those formulæ agree perfectly with the analytical results; but in respect to the assumed proximate constitutions of these salts, the only evidence that can be offered in proof of their accuracy is, that the relations of the salts to all other salts of the indigo series are such as would exist if the constitutions that are *assumed* to be true, could be *proved* to be true. The great assumption made in respect to indigo white is, that it contains a salt of Ammonium combined with a salt of Amidogen. Hitherto, such combinations have not been admitted, because they have been overlooked and misunderstood; but the numerous examples of their existence which I have cited in this Essay must remove all reasonable doubts respecting the possibility of their existence.

3]. One of the agents employed to reduce indigo blue to indigo white is grape sugar, and the process of reduction may be represented as follows:—

EMPLOYED:			PRODUCED:	
$\left\{\begin{matrix} ZH^2,C^8H^3O \\ ZH^2,C^8H^3O \end{matrix}\right\}$	$+ CH^2O$	$+ H^2O.$	$\left\{\begin{matrix} ZH^2,C^8H^3O \\ ZH^4,C^8H^3O \end{matrix}\right\}$	$+ H,CHO^2.$
Indigo blue, 2 atoms.	Grape sugar.	Water.	Indigo white, 1 atom.	Formic acid.

A more elaborate and intricate explanation of this process, founded on the current theory of chemistry, is given in Professor Gregory's *Handbook of Organic Chemistry*, page 365.

Indigo white is subject to reconversion into indigo blue by a process which is usually called "oxidation;" that is to say, when it is exposed to atmospheric air, O^1 of the air takes H^2 from the indigo to form water; the ammonium ZH^4 is thus "oxidised" into the amidogen ZH^2, and the indigo white again becomes indigo blue.

If the theory, according to which I am endeavouring to explain the constitution of the indigo salts, is true, it shows, among other things, that the processes which are commonly called *oxidation* and *reduction*, are either incorrectly understood by chemists, or are described in very awkward phraseology. Let us consider the present case in detail. We convert two atoms of indigo blue into one atom of indigo white, by the *addition of two atoms of hydrogen*, and we call this process "reduction." What is reduced? Surely not the indigo. We reverse the operation. We convert one atom of indigo white into two atoms of indigo blue, by *taking away two atoms of hydrogen*, and this process we call "oxidation." What is oxidised? Certainly not the indigo. The ways and means by which the results are brought about are, theoretically, of no moment. The facts are, that *hydrogen* is either added or removed. The words intimate that *oxygen* is added or removed. Many of the misty hypotheses that have been published respecting the metamorphoses of the various salts of indigo have no doubt had their origin in the ambiguity that has been occasioned by the abuse of the words oxidation and reduction.

4]. $ZH^2 ; C^8H^3O^2$ = Amida indylete.

Indigo blue, when submitted to the action of certain agents which impart oxygen, such as nitric acid and chromic acid, takes up another atom of oxygen, and produces the compound which is usually called ISATINE, and which possesses the following constitution:

$ZH^2 ; C^8H^3O^2$ = Amida indylete.

This compound differs from indigo blue by containing an additional atom of oxygen. Berzelius called it Indenoxyd. Gmelin's formula is $C^{16}NH^5O^2,O^2$. Laurent's formula $C^{16}H^5NO^4$.

5]. $ZHK\ ; C^8H^3O^2$ = Potassac indylete.
6]. $ZHAg ; C^8H^3O^2$ = Argentac indylete.

When Amida indylete—Isatine—is acted on by a *cold* solution of caustic potash, it exchanges an atom of hydrogen for an atom of potassium, by which exchange its positive radical amida is converted into potassac.

$$ZH^2 ; C^8H^3O^2 + KHO = ZHK ; C^8H^3O^2 + HHO.$$

A similar salt, 6], can be prepared with silver, and indeed the formula ZHM^r; $C^8H^3O^2$ is that of a series of salts which contain amidac radicals. These salts are called by different chemists, *Isatites*, *Isatides*, and *Isatinides*. Their usual formula is $C^{16}NH^4MO^4$.

$$7].\ \begin{cases} ZH^3K\ ;\ C^8H^3O^3 = \text{Potassam indylite.} \\ ZH^3Ag\ ;\ C^8H^3O^3 = \text{Argentam indylite.} \\ ZH^3Ba\ ;\ C^8H^3O^3 = \text{Barytam indylite.} \end{cases}$$

$$8].\ ZH^4\ ;\ C^8H^3O^3 = \text{Ammona indylite.}$$

When Amida indylete—Isatine, No. 4]—is acted on by a *hot* solution of caustic potash, the power of the azotic radical is enlarged, the amida becomes potassam, and the salt assumes another atom of oxygen. Thus:

$$ZH^2;\ C^8H^3O^2 + KHO = ZH^3K;\ C^8H^3O^3.$$

By proper operations, the experimental details of which do not belong to this investigation, the potassium in this salt can be replaced by barium, silver, or hydrogen; giving origin to salts that agree with the formulæ marked 7] and 8].

It is important to notice the difference of the effects that are produced by treating isatine with a *hot* and with a *cold* solution of caustic potash. The relations of amidogens to ammoniums are often essentially changed by circumstances that chemists overlook as insignificant.

By one of those misnomers that are so frequent in organic chemistry, the normal salt of this series, represented by No. 8], is called an "ACID." Gregory calls it ISATINIC ACID; and Miller's name for it is ISATIC ACID. The denomination "acid" is founded on the assumption, that the atom of azote, and three out of the four atoms of hydrogen which are here ascribed to the basic radical of the salt, all belong to the acid radical. Of course, there is no evidence to support that notion. According to the theory now under consideration, the Isatinic or Isatic acid corresponding with the salts 7] and 8], would be constituted as follows, $H^r,C^8H^3O^3$; but no such compound is known. The other salts cited above are commonly called Isatate of potash, Isatate of silver, and Isatate of barytes. The formula usually ascribed to the imaginary isatic acid is $C^{16}NH^7O^6$, or $HO,C^{16}H^6NO^5$.

Formula 8] and formula 4] show, that hydrated isatic acid is the neutral salt of ammonia of which isatine is the amide. That is, I believe, the true relation of these two salts. It will be seen that a great many of the salts of the indigo series differ from one another to the extent of the difference in the quantity of hydrogen that is required to convert an amid ZH^2 into an ammon ZH^4; all other constituents of the salts, except oxygen, remaining the same. Of course, this peculiarity is not confined to the indigo series, but is a general property of the azotic radicals.

$$9].\ \left\{\begin{matrix} ZH^4;\ C^8H^3O^2 \\ ZH^2;\ C^8H^3O^2 \end{matrix}\right\} = \text{Ammona indylete cum amida indylete.}$$

When "reducing" agents are made to act upon isatine = $ZH^2; C^8H^3O^2$, the result is exactly similar to that produced when they act upon blue indigo; namely, two atoms of isatine take up two atoms of hydrogen, and produce a compound which has the composition represented by formula 9]. This compound differs from white indigo by containing two additional atoms of oxygen, just as isatine differs from blue indigo by containing one additional atom of oxygen. The name that is usually given to it is ISATHYDE. Berzelius called it Isatenoxyd. Its ordinary formula is $C^{16}H^6NO^4$.

$$10].\ \left\{\begin{matrix} ZH^4;\ C^8H^3O^2 \\ ZH^2;\ C^8H^3O \end{matrix}\right\} = \text{Ammona indylete cum amida indylate.}$$

The salt 9] rests upon the experiments of Laurent. Erdmann considers the salt to have the composition that is indicated by the common formula $C^{16}H^6NO^3$, which is equivalent to formula No. 10]. A compound of this per centage composition has been described under the name of Isatan, which Berzelius rendered Isaten sesquioxydul.

I proceed to quote a few examples of the salts of indigo that contain the chloric and bromic vice-radicals.

11]. $ZH^2\ ; C^8H^2ClO^2$ = Amida chloric-indylete.
12]. $ZHAg; C^8H^2ClO^2$ = Argentac chloric-indylete.

The salt No. 11] differs from the salt No. 4] only by containing chloric indyl = C^8H^2Cl, instead of normal indyl = C^8H^3. The salt No. 12] differs from the salt No. 6] only by the same substitution.

The ordinary names for the salt No. 11] are chlorisatine and chlorisatinase, and the formula is $C^{16}H^4ClNO^4$. Berzelius's formula is $C^{16}H^4NO^3,ClO$, and his name is Basisches unterchlorigsaures porrindensesquioxydul!

13]. $ZH^2; C^8H^2BrO^2$ = Amida bromic-indylete.

The common names are bromisatine and bromisatinase = $C^{16}NBrH^4O^4$.

14]. $ZH^2; C^8HCl^2O^2$ = Amida chlorenic-indylete.

Common name: Bichlorisatine = $C^{16}NCl^2H^3O^4$. Berzelius's formula (translated from the Greek) is $C^{16}H^3NO^2,2ClO$. His name is Unterchlorigsaures flavindenoxydul.

A comparison of the formulæ No. 11] and No. 14] with Berzelius's names and formulæ for the same compounds, will show how far that great chemist was led astray by his misconception of the nature of the compounds which I have called VICE-RADICALS.

15]. ZH^2 ; $C^8HBr^2O^2$ = Amida bromenic-indylete.
16]. ZHK ; $C^8HBr^2O^2$ = Potassac bromenic-indylete.

Common names: No. 15] is Bibromisatine, bromisatinese = $C^{16}NBr^2H^3O^4$, *Laurent*. No. 16] is called Bibromisatite of potash = $C^{16}H^2KBr^2NO^4$, *Gerhardt*.

17]. ZH^3K ; $C^8H^2ClO^3$ = Potassam chloric-indylite.
ZH^3Ba ; $C^8H^2ClO^3$ = Barytam chloric-indylite.
ZH^3Ag ; $C^8H^2ClO^3$ = Argentam chloric-indylite.
ZH^3Pb ; $C^8H^2ClO^3$ = Plumbam chloric-indylite.
18]. ZH^4 ; $C^8H^2ClO^3$ = Ammona chloric-indylite.

The salts represented by formulæ 17] and 18] are commonly called Chlorisatates and Chlorisatinates, and the usual formula is $C^{16}NClH^5MO^6$. No. 18] is the Chlorisatic "Acid," in agreement with the formula $HO,C^{16}H^5NClO^5$. Berzelius's name for it is Indenoxydul chlorige Säure. This "acid" cannot be separated from solution, and is, in fact, unknown.

The series 17] and 18] agree precisely with the series 7] and 8], except in containing chloric-indyl instead of normal indyl.

19]. ZH^3K ; $C^8HCl^2O^3$ = Potassam chlorenic-indylite.
ZH^3Ba ; $C^8HCl^2O^3$ = Barytam chlorenic-indylite.
ZH^3Cuc ; $C^8HCl^2O^3$ = Cupricam chlorenic-indylite.
ZH^3Pb ; $C^8HCl^2O^6$ = Plumbam chlorenic-indylite.
ZH^3Ag ; $C^8HCl^2O^3$ = Argentam chlorenic-indylite.
20]. ZH^4 ; $C^8HCl^2O^3$ = Ammona chlorenic-indylite.

The salts represented by the formulæ No. 19] are commonly called Bichlorisatinates. No. 20] is the Bichlorisatinic "Acid," answering to the formulæ $HO,C^{16}H^4Cl^2NO^5$ or $C^{16}NCl^2H^5O^6$. Berzelius's name for this acid is Porrinden-chloric acid = $C^{16}H^4N,Cl + ClO^5 + HO$.

The relation of these salts to those represented by formulæ 7], 8], and 17], 18], is so evident, that it is needless to offer any discussion.

21]. ZH^4; $C^8H^2BrO^3$ = Ammona bromic-indylite.

Common name: Bromisatic acid = $C^{16}NBrH^6O^6$. Compare it with 18].

22]. ZH^3K ; $C^8HBr^2O^3$ = Potassam bromenic-indylite.
23]. ZH^4 ; $C^8HBr^2O^3$ = Ammona bromenic-indylite.

Commonly called Bibromisatinates. No. 23 is the Bibromisatinic "Acid" = $HO,C^{16}H^4Br^2NO^5$. Compare 22] with 19], and 23] with 20].

The relations existing between the following pairs of salts are so evident, that it seems to be scarcely necessary to point them out:

Normal Salts of Ammoniums.		Corresponding Amides.	
No. 18].	$ZH^4 \; ; C^8H^2Cl\,O^3$	[No. 11].	$ZH^2 \; ; C^8H^2Cl\,O^2$
17].	$ZH^3Ag ; C^8H^2Cl\,O^3$	12].	$ZHAg ; C^8H^2Cl\,O^2$
21].	$ZH^4 \; ; C^8H^2Br\,O^3$	13].	$ZH^2 \; ; C^8H^2Br\,O^2$
20].	$ZH^4 \; ; C^8H\,Cl^2\,O^3$	14].	$ZH^2 \; ; C^8H\,Cl^2\,O^2$
23].	$ZH^4 \; ; C^8H\,Br^2O^3$	15].	$ZH^2 \; ; C^8H\,Br^2O^2$
22].	$ZH^3K \; ; C^8H\,Br^2O^3$	16].	$ZHK \; ; C^8H\,Br^2O^2$.

24]. $\left\{\begin{matrix} ZH^4 ; C^8H^2ClO^2 \\ ZH^2 ; C^8H^2ClO^2 \end{matrix}\right\}$ Ammona chloric-indylete cum amida chloric-indylete.

The ordinary names of this salt are as follow: Chlorisathyde = $C^{32}H^{10}Cl^2N^2O^6$, *Gerhardt*. Chlorisathydase, *Laurent*. Basisches unterchlorigsaures indensesquioxydul = $C^{16}H^5NO^3 + ClO$, *Berzelius*.

25]. $\left\{\begin{matrix} ZH^4 ; C^8HCl^2O^2 \\ ZH^2 ; C^8HCl^2O^2 \end{matrix}\right\}$ Ammona chlorenic-indylete cum amida chlorenic-indylete.

Common names: Chlorisathydese, *Laurent*. Bichlorisathyde = $C^{32}H^8Cl^4N^2O^8$. Unterchlorigsaures porrindenoxydul = $C^{16}H^4NO^2,2ClO$, *Berzelius*.

Compare the salts No. 24] and 25] with normal isathyde, No. 9]. It is evident that the three salts differ in no other respect than that, in two of them, a portion of the hydrogen of the radical indyl is replaced by chlorine. Yet Berzelius thought it proper to assume that these salts contained three totally-different radicals—isaten, inden, and porrinden; and that these radicals were present in remarkable conditions of combination. Thus, 9] was the "peroxide of isaten;" 24] was the "basic hypochlorite of the sesquioxide of inden;" and 25] was the "hypochlorite of the protoxide of porrinden." Here we see how things which are naturally simple and regular can be distorted and made perplexing by the vices of an erroneous hypothesis. Berzelius would not admit that chlorine could replace hydrogen in radicals, and he was driven to advance a host of assumptions, each of which was a thousand times more incredible than the single assumption which he repudiated.

Section 2.—SALTS IN WHICH INDYLAC IS THE NEGATIVE RADICAL.

I mean by INDYLAC, a vice-amid which contains one atom of Indyl $= ZH,C^8H^3$.

26]. $ZH^2 ; ZH,C^8H^3O$ = Amida indylacate.
27]. $ZH^2 ; ZH,C^8H^2ClO$ = Amida chloric-indylacate.
28]. $\left\{\begin{matrix} ZH^2 ; ZH,C^8H^3O \\ ZH^2 ; \quad C^8H^3O^2 \end{matrix}\right\}$ = Amida indylacate cum amida indylete.

29]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^2Cl\,O} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^2Cl\,O^2}\end{array}\right\}$ = Amida chloric-indylacate cum amida chloric-indylete.

30]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8HBr^2O} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8HBr^2O^2}\end{array}\right\}$ = Amida bromenic-indylacate cum amida bromenic-indylete.

31]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^3O} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^3O^2} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^3O^2}\end{array}\right\}$ = Amida indylacate bis amida indylete.

32]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^3O} \\ \mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^3O} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^3O^2}\end{array}\right\}$ = Bis amida indylacate cum amida indylete.

33]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8HBr^2O} \\ \mathrm{ZH^2} & ;\ \mathrm{ZH,C^8HBr^2O} \\ \mathrm{ZH^2} & ;\ \mathrm{ZH,C^8HBr^2O} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8HBr^2O^2}\end{array}\right\}$ = Tris amida bromenic-indylacate cum amida bromenic-indylete.

34]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^3O} \\ \mathrm{ZH^4} & ;\ \mathrm{ZH,C^8H^3O^2}\end{array}\right\}$ = Amida indylacate cum ammona indylaccete.

35]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8H^2ClO} \\ \mathrm{ZH^4} & ;\ \mathrm{ZH,C^8H^2ClO^2}\end{array}\right\}$ = Amida chloric-indylacate cum ammona chloric-indylaccete.

36]. $\left\{\begin{array}{ll}\mathrm{ZH^2} & ;\ \mathrm{ZH,C^8HCl^2O} \\ \mathrm{ZH^4} & ;\ \mathrm{ZH,C^8HCl^2O^2}\end{array}\right\}$ = Amida chlorenic-indylacate cum ammona chlorenic-indylaccete.

37]. $\left\{\begin{array}{ll}\mathrm{ZH^4} & ;\ \mathrm{ZH,C^8H^3O^2} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^3O^2}\end{array}\right\}$ = Ammona indylaccete cum amida indylete.

38]. $\left\{\begin{array}{ll}\mathrm{ZH^4} & ;\ \mathrm{ZH,C^8H^2Cl\,O^2} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H^2Cl\,O^2}\end{array}\right\}$ = Ammona chloric-indylaccete cum amida chloric-indylete.

39]. $\left\{\begin{array}{ll}\mathrm{ZH^4} & ;\ \mathrm{ZH,C^8H\,Cl^2O^2} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8H\,Cl^2O^2}\end{array}\right\}$ = Ammona chlorenic-indylaccete cum amida chlorenic-indylete.

40]. $\left\{\begin{array}{ll}\mathrm{ZH^3Ba} & ;\ \mathrm{ZH,C^8H^3O^2} \\ \mathrm{ZH^2} & ;\ \quad \mathrm{H\,C^8H^3O^2}\end{array}\right\}$ = Barytam indylaccete cum amida indylete.

41]. $\left\{\begin{array}{ll}\mathrm{ZH^3Ag} & ;\ \mathrm{ZH,C^8HCl^2O^2} \\ \mathrm{ZH^2} & ;\ \qquad \mathrm{C^8HCl^2O^2}\end{array}\right\}$ = Argentam chlorenic-indylaccete cum amida chlorenic-indylete.

42]. $\mathrm{ZH^4}\ ;\ \mathrm{ZH,C^8H^3O^2}$ = Ammona indylaccete.

43]. $\mathrm{ZH^2Cuc^2};\ \mathrm{ZH,C^8H^3O^2}$ = Cupriccem indylaccete.

44]. $\mathrm{ZH^3Ag}\ ;\ \mathrm{ZH,C^8H^3O^2}$ = Argentam indylaccete.

45]. $\mathrm{ZH^3Ag}\ ;\ \mathrm{ZH,C^8H^2ClO^2}$ = Argentam chloric-indylaccete.

I have placed the above formulæ together, in order to show the relationship of the multiple salts of indigo, and to draw attention to the slight, but perfectly definite, differences by which they are individually characterised.

All the formulæ from 26] to 45], contain an assumption that appeared in none of the formulæ from 1] to 25]. This consists in the employment of a vice-amidogen, INDYLAC = ZH,C^8H^4, as an ACID RADICAL. I shall be asked, how I justify so novel and irregular a proceeding? I reply, by the success with which it is followed. No assumption hitherto made by chemists has availed to raise the formulæ of the indigo salts out of the mists of empiricism. With *this* assumption, their composition is made intelligible and regular. The end justifies the means, because order is better than muddle.

NOTICES OF THE INDIVIDUAL SALTS.

No. 26]. $ZH^2; ZH,C^8H^3O$ = Amida indylacate.
Compare with No. 4]. $ZH^2; \quad C^8H^3O^2$ = Amida indylete (*Isatine*).

When isatine is treated with ammonia ZH^2,H, the compound No. 26] is produced, one atom of water H,HO being given off.

$$ZH^2; C^8H^3O^2 + ZH^2H = ZH^2; ZH,C^8H^3O + H,HO.$$

In this operation, the residue of the ammonia ZH, combines with the indyl C^8H^3 to form the vice-amidogen *Indylac*. The resulting salt 26] if formulated "on the model of water" would look thus: $\left.\begin{matrix} ZH^2 \\ ZH,C^8H^3 \end{matrix}\right\} O$. If we contrast the radicals ZH^2 with ZH,C^8H^3, and ask which is the more acid of the two, taking for our guidance the properties of radicals which have been described at page 73 of this work, we come to the conclusion that ZH,C^8H^3 is more acid than ZH^2, and consequently that the proper formula for the compound which contains both is that given in 26] = $ZH^2; ZH,C^8H^3O$.

The ordinary names of this compound are as follow: Imesatine = $C^{16}H^6N^2O^2$, *Gerhardt*. Porrindenoxydulamid = $C^{16}H^4NO^2NH^2$, *Berzelius*.

27]. $ZH^2; ZH,C^8H^2ClO$ = Amida chloric-indylacate.

This salt differs from No. 26] only in containing chloric-indyl = C^8H^2Cl instead of indyl = C^8H^3. It is prepared by acting upon chlorisatine instead of normal isatine. This remark applies to the salts of the vice-indyls generally. Whatever compound salt you can make with indyl, you can also make with chloric-, chlorenic-, bromic-, or bromenic-indyl. I cannot go into experimental details, and it is needless to repeat this general remark at the mention of every formula.

The ordinary names for No. 27] are chlorimesatine = $C^{16}H^5ClN^2O^2$, *Gerhardt*. Imechlorisatinase, *Laurent*.

28]. $\left\{\begin{matrix} ZH^2; & ZH,C^8H^3O \\ ZH^2; & C^8H^3O^2 \end{matrix}\right\}$ = Amida indylacate cum amida indylete.

A compound of the two salts, 26] and 4], atom to atom.

Usual names: Imasatine = $C^{32}H^{11}N^{3}O^{6}$, *Gerhardt*. Polindenoxyd = $C^{32}H^{11}N^{3},O^{6}$, *Berzelius*.

29]. The chlorine compound parallel to 28].

Common name: Chlorimasatine = $C^{32}H^{9}Cl^{2}N^{3}O^{6}$, *Gerhardt*. Imachlorisatine, *Strecker*.

30]. The bromine compound parallel to 28].

Usual names: Bibromimasatine = $C^{32}H^{7}Br^{4}N^{3}O^{6}$, *Gerhardt*. Imabibromisatine, *Strecker*.

$$31]. \left\{\begin{array}{ll} ZH^{2}; & ZH,C^{8}H^{3}O \\ ZH^{2}; & C^{8}H^{3}O^{2} \\ ZH^{2}; & C^{8}H^{3}O^{2} \end{array}\right\} = \text{Amida indylacate bis amida indylete.}$$

A compound of one atom of the salt 26] with two atoms of the salt 4].

Common name: Isatilime = $C^{48}H^{16}N^{4}O^{10}$, *Laurent*.

$$32]. \left\{\begin{array}{ll} ZH^{2}; & ZH,C^{8}H^{3}O \\ ZH^{2}; & ZH,C^{8}H^{3}O \\ ZH^{2}; & C^{8}H^{3}O^{2} \end{array}\right\} = \text{Bis amida indylacate cum amida indylete.}$$

A compound of two atoms of 26] with one atom of 4].

The ordinary name of this salt is Isatimide = $C^{48}H^{17}N^{5}O^{8}$, *Laurent*. Compare the single salt 26] with the three multiple salts 28], 31], 32].

33]. A salt, said to be very beautiful, accidentally obtained by Laurent, but not producible at pleasure. His name and formula are, Carmindine bibromée = $C^{64}H^{15}Br^{2}N^{7}O^{10}$.

The most interesting circumstance respecting this salt is, that it seems to indicate the existence of salts that belong to the series 26], 28], 31], 32], but extending beyond the last of these.

$$34]. \left\{\begin{array}{ll} ZH^{2}; & ZH,C^{8}H^{3}O \\ ZH^{4}; & ZH,C^{8}H^{3}O^{2} \end{array}\right\} = \text{Amida indylacate cum ammona indylaccete.}$$

This salt is procured by heating the isamate of ammonia No. 42]. HHO is driven off, and No. 34] remains.

$$\left.\begin{array}{ll} ZH^{4}; & ZH,C^{8}H^{3}O^{2} \\ ZH^{4}; & ZH,C^{8}H^{3}O^{2} \end{array}\right\} = \left\{\begin{array}{ll} ZH^{2}; & ZH,C^{8}H^{3}O \\ ZH^{4}; & ZH,C^{8}H^{3}O^{2} \end{array}\right\} + H,HO.$$

The compound thus procured contains one atom of the salt 26] and one of the salt 42]. Compare 34] with 10]. The difference between the two salts is, that the two atoms of indyl in 10] are replaced by two atoms of indylac in 34].

Common names: Isamide, Amasatine = $C^{32}H^{14}N^{4}O^{6}$, *Laurent* and *Gerhardt*. Polindenoxydammoniak = $C^{32}H^{11}N^{3}O^{6} + NH^{3}$, *Berzelius*.

35], 36]. These salts correspond to 34] but have chloric- and chlorenic-indyl instead of indyl. Common names:

No. 35]. Chlorisamide = $C^{32}H^{12}Cl^{2}N^{4}O^{6}$.
No. 36]. Bichlorisamide = $C^{32}H^{10}Cl^{4}N^{4}O^{6}$.

$$37].\ \left\{\begin{array}{ll} ZH^4; & ZH,C^8H^3O^2 \\ ZH^2; & C^8H^3O^2 \end{array}\right\} = \begin{array}{c}\text{Ammona indylaccete cum} \\ \text{amida indylete.}\end{array}$$

$$\text{Compare with}\quad 9].\ \left\{\begin{array}{ll} ZH^4; & C^8H^3O^2 \\ ZH^2; & C^8H^3O^2 \end{array}\right\} = \begin{array}{c}\text{Ammona indylete cum} \\ \text{amida indylete.}\end{array}$$

The only difference in the composition of the two salts, Nos. 9] and 37] is, that in the latter one atom of indyl is replaced by one atom of indylac. The salt 37] contains one atom of isamate of ammonia 42] combined with one atom of isatine 4]. It is procured by acting upon isatine with ammonia.

$$\left.\begin{array}{l} ZH^2;\ C^8H^3O^2 + ZH^2H \\ ZH^2;\ C^8H^3O^2 \end{array}\right\} = \left\{\begin{array}{ll} ZH^4; & ZH,C^8H^3O^2 \\ ZH^2; & C^8H^3O^2 \end{array}\right.$$

The common names of this compound (No. 37) are as follow: Isamic acid; Imasatic acid = $C^{32}H^{13}N^3O^8$, *Gerhardt*. Imasatinic acid, *Laurent*. Isatinamic acid. Rubindenic acid, *Berzelius*. Isamsäure = $HO, C^{32}H^{12}N^3O^7$, *Strecker*.

38] and 39] are salts similar to 37] but containing chloric and chlorenic-indyl instead of indyl. No. 38] is commonly called chlorisamic acid = $HO,C^{32}H^{10}Cl^2N^3O^7$. No. 39] is called Bichlorisamic acid = $HO,C^{32}H^8Cl^4N^3O^7$.

40]. This is the barium salt of the Isamic acid, No. 37]. Between the composition of No. 37] and No. 40], there is only the difference that Ammona = ZH^4 is replaced by Barytam = ZH^3Ba. The ordinary name for the salt represented by No. 40] is Isamate of barytes = $BaO,C^{32}H^{12}N^3O^7$.

41]. This is the silver salt of the "acid" formulated by No. 39]. Its common name is the Bichlorisamate of silver.

$$42].\ ZH^4;\ ZH,C^8H^3O^2 = \text{Ammona indylaccete.}$$

This is the ammonia salt of the "acid" formulated by No. 37]. It is formed thus:

$$\left.\begin{array}{ll} ZH^4; & ZH,C^8H^3O^2 \\ ZH^2; & C^8H^3O^2 + ZH^2,H \end{array}\right\} = \left\{\begin{array}{l} ZH^4;\ ZH,C^8H^3O^2 \\ ZH^4;\ ZH,C^8H^3O^2 \end{array}\right.$$

As I consider the salt No. 37] to be a compound of two salts, so I consider the result of this reaction to be a product of two similar salts, and therefore I limit the formula to what is given in 42].

The common name of 42] is the isamate of ammonia. I have already stated that when it is strongly dried, the loss of water transforms it into the salt No. 34].

$$43].\ ZH^2Cuc^2;\ ZH,C^8H^3O^2 = \text{Cupriccem indylaccete.}$$
$$44].\ ZH^3Ag;\ ZH,C^8H^3O^2 = \text{Argentam indylaccete.}$$

These two salts are modifications of No. 42], the ammona of 42] being replaced by Cupriccem in 43] and by Argentam in 44]. Common names: No. 43] is Isatinkupferammonium = $C^{16}NH^2(NH^4)Cu^2O^4$, or $C^{16}N^2H^6Cu^2O^4$, *Gmelin*. Isatinkupferoxydammoniak = $2CuO,C^{16}H^3NO^2 + NH^3$, *Strecker*.

No. 44] is Isatinsilverammonium = $C^{16}NH^3(NH^4)AgO^4$, *Gmelin*. $C^{16}NH^4(NH^3Ag)O^4$, *Laurent*. Isatinsilberoxydammoniak = $AgO, C^{16}H^4NO^3 + NH^3$, *Strecker*.

45]. $ZH^3Ag; ZH,C^8H^2ClO^2$ = Argentam chloric indylaccete. This salt differs from No. 44] only by containing chloric-indyl instead of indyl. Common names: Chlorisatinsilverammonium = $C^{16}NClH^2(NH^4)AgO^4$, *Gmelin*. $AgO.C^{16}H^3ClNO^3 + NH^3$, *Strecker*. Chlorisatite of argentammonium = $C^{16}H^3(NH^3Ag)ClNO^4$, *Gerhardt*.

SECTION 3.—SALTS IN WHICH INDYLAC AND INDYLAM ACT AS POSITIVE RADICALS, WITH SULPHUR AS A NEGATIVE RADICAL.

Indylac, as already explained, is a vice-amid containing one atom of Indyl = ZH,C^8H^3. Indylam is a vice-ammon containing one atom of Indyl = ZH^3,C^8H^3.

A. *Bisulphates.*

46]. $$\left\{\begin{matrix} ZH^3,C^8H^3; SO^2 \\ H; SO^2 \end{matrix}\right\} = \text{Hydra indylam sulphenote.}$$

47]. $$\left\{\begin{matrix} ZH^3,C^8H^3; SO^2 \\ ZH^4 \quad ; SO^2 \end{matrix}\right\} = \text{Ammona indylam sulphenote.}$$

48]. $$\left\{\begin{matrix} ZH\ ,C^8H^3; SO^2 \\ H; SO^2 \end{matrix}\right\} = \text{Hydra indylac sulphenote.}$$

49]. $$\left\{\begin{matrix} Pb; ZH,C^8H^3; 8^2O^4 = \text{Plumba indylac sulphenote.} \\ K; ZH,C^8H^3; S^2O^4 = \text{Potassa indylac sulphenote.} \\ Ba; ZH,C^8H^3; S^2O^4 = \text{Baryta indylac sulphenote.} \end{matrix}\right.$$

B. *Sulphite.*

50]. $$\left\{\begin{matrix} \left.\begin{matrix} ZH^3,C^8H^3; SO \\ ZH^3,C^8H^3; SO^2 \end{matrix}\right\} = \\ = ZH^3,C^8H^3; ZH^3,C^8H^3; S^2O^3 \end{matrix}\right\} = \text{Indylamen sulphenite.}$$

C. *Hyposulphite ?*

51]. $ZH^3,C^8H^3; S^2O$? = Indylam sulphenate.

46]. $$\left\{\begin{matrix} ZH^3,C^8H^3; SO^2 \\ H; SO^2 \end{matrix}\right\} = \begin{matrix} \text{Hydra indylam sulphenote.} \\ \text{(or, Hydra indylam bisulphete.)} \end{matrix}$$

This salt is the Acide sulfisataneux of *Laurent*, the Sulfisatanige Säure o *Strecker*. Formulæ: $HO,C^{16}H^6NO^3,2SO^2$. I cannot understand why those proportions of sulphur, oxygen, and basic radicals which constitute what is commonly called a sulphate should ever be considered to form a sulphite. Organic chemists are too often guided in their opinion of what a salt IS, by their knowledge of the materials they use to make it, or the products they obtain when they decompose it. A salt, while it exists, is neither its antecedent nor its subsequent. Its name ought to state *what it is*, and not allude to circumstances that attend its construction or destruction.

A sulphate contains one positive radical, one atom of sulphur, and two atoms of oxygen. A sulphite contains two positive radicals, two atoms of sulphur, and three atoms of oxygen. These, at least, are the relations insisted upon by the radical theory, but, under all theories, these salts present differences which no chemist is entitled to overlook.

47]. $ZH^4;\ ZH^3,C^8H^3;\ S^2O^4$ = Ammona indylam sulphenote.

This is the ammonia-salt of the "acid" No. 46]. Its usual names are Sulfisatanite d'ammoniaque, *Laurent*. Sulfisatanigsaures ammoniak, *Strecker*. Formula: $C^{16}H^{10}N^2S^2O^8$ (with 2Aq. omitted in the above formula). This salt is not readily decomposed. Hydrochloric acid does not disengage sulphurous acid from its solution. Salts of barium produce no precipitate therein. The salt No. 47] is prepared by mixing bisulphite of ammonia with an alcoholic solution of sulphesatyde.

48]. $H;\ ZH,C^8H^3;\ S^2O^4$ = Hydra indylac sulphenote.
49]. $K;\ ZH,C^8H^3;\ S^2O^4$ = Potassa indylac sulphenote.

The "acid" No. 48] differs from the "acid" No. 46] only by containing indylac instead of indylam; all other things remaining the same. The salts 49] differ from the salt 47] in the same particular. The difference is the same as that which distinguishes the Binoxalates from the Oxamates. The acid 48] is prepared by digesting indigo blue in concentrated hydrated sulphuric acid in a close vessel:

$$\left.\begin{array}{r} ZH^2,C^8H^3O \\ H,\quad SO^2 \\ H,\quad SO^2 \end{array}\right\} = \left\{\begin{array}{l} \left.\begin{array}{r} ZH,C^8H^3;\ SO^2 \\ H;\ SO^2 \end{array}\right\}\text{No. 48].} \\ \quad\quad\quad\ \ H,HO = \text{water.} \end{array}\right.$$

With diluted acid, and free access of air, the salt No. 57] is produced. The acid No. 48] has received a variety of names, and been the subject of many different hypotheses. Sulphate of indigo; Cœrulin-sulphuric acid, *W. Crum;* Sulphindigotic acid; sometimes, hyposulphindigotic acid; indigblauschwefelsäure; Schwefelsaurer indigo; Lösliches indigblau; Indylinschwefelsäure; Sulfindylsäure; Acide sulfindylique, *Dumas;* Acide sulfindigotique. Formulæ: $C^{16}NH^5S^2O^8 = C^{16}NH^5O^2,2SO^3$, *Gmelin*. $HO,C^{16}H^4NO,2SO^3$ (= Sulphindylic acid), *Miller*. The salts 49] are commonly called Sulphindylates. The usual formula of the potash salt is $KO,C^{16}H^4NO,S^2O^6$. It has also been called Indigo carmine and soluble indigo.

I copy the following passage from Dr. Gregory's account of the salts No. 49]. "The sulphindigotate appears to be strictly a hyposulphindigotate, and its formula is in all probability, $C^{16}H^{4}NO^{2},S^{2}O^{5} + KO$. Dumas' view, according to which the salt is a double sulphate, analogous to sulphovinate of potash, $C^{16}H^{4}NO,SO^{3} + KO,SO^{3}$, is not supported by the chemical relations of these substances. Dumas conjectured that indigo blue was analogous to alcohol, and that its formula was $C^{16}H^{4}N,O + HO$, the body $C^{16}H^{4}N,O$ being analogous to oxide of ethyle. But this view is far-fetched, and does not agree with the chemical relations of indigo. It would make, for example, white indigo $C^{16}H^{4}N,O + H + HO$ or $C^{16}NH^{4} + 2HO$, both most improbable formulæ." *Handbook of Organic Chemistry* (1856), p. 367.

I disagree entirely with Dumas' view, that indigo blue has a structure analogous to that of alcohol, and I have shown that its structure resembles that of an amide:

$$\begin{aligned} H\,,C^{2}H^{5}O &= \text{Alcohol.} \\ ZH^{2},C^{8}H^{3}O &= \text{Indigo blue.} \\ ZH^{2},C^{2}H^{3}O &= \text{Acetamide.} \end{aligned}$$

Nevertheless, I agree with Dumas, that the structure of sulphate of indigo resembles that of sulphovinate of potash; the two salts being formulated in my notation as follow:

$$K;\ C^{2}H^{5}\quad;\ S^{2}O^{4} = \begin{cases} \text{Sulphovinate of potash.} \\ \text{Potassa ethyla sulphenote.} \end{cases}$$

$$K;\ ZH,C^{8}H^{3};\ S^{2}O^{4} = \begin{cases} \text{Indigotate of potash.} \\ \text{Potassa indylac sulphenote.} \end{cases}$$

The sole difference exhibited by these two salts, is the replacement of ethyla by indylac, both of which are basic radicals. It is not very clear what Dr. Gregory means by a hyposulphindigotate. The formula that he proposes for the salt shows those proportions of S and O which constitute a sulphate, not a hyposulphate; moreover, a hyposulphate, though it is biacid, is monobasic (see page 172), and it could only have indigo and potassium together, as a base in the form of an amidogen or ammonium. The respective quantities of the oxygen and sulphur, however, agree with the composition of nothing but a double sulphate.

50]. $ZH^{3},C^{8}H^{3};\ ZH^{3},C^{8}H^{3};\ S^{2}O^{3}$ = Indylamen sulphenite.

This salt is what, in the existing nomenclature, would be called the "neutral sulphite" of indylam. It is the Sulfasatyde, or Sulfisathyde of *Laurent* and *Erdmann;* the Isatenoxysulphuret of *Berzelius.* Formulæ: $C^{16}H^{6}NO^{3}S$, *Laurent.* $C^{32}H^{12}N^{2}O^{6}S^{2}$, *Gerhardt.* $3C^{16}H^{6}NO^{4} + C^{16}H^{6}NS^{4}$, *Berzelius.*

51]. $ZH^{3},C^{8}H^{3};\ S^{2}O$ = Indylam sulphenate.

This salt is given on the authority of Laurent, after whom it is copied into all the works on Chemistry. The ordinary names and formulæ are

Sulfésathyde, Isathyde bisulfurée = $C^{16}H^6NO^2S^2$, *Laurent*. Bisulfisathyde = $C^{32}H^{12}N^2O^4S^4$, *Gerhardt*. Isatenoxysulphuret = $C^{16}H^6NO^4 + C^{16}H^6NO^4$, *Berzelius*. The salt is prepared by passing sulphuretted hydrogen into a solution of isatine. The formula 51] is an uncommon form of an oxysalt of sulphur, and I think that the true formula of the salt is that of a hyposulphite:

$$\text{Either } \left\{\begin{matrix} ZH^3,C^8H^3; SO \\ H; SO \end{matrix}\right\} \text{ or } \left\{\begin{matrix} ZH^3,C^8H^3; SO \\ ZH^3,C^8H^3; SO \\ S; SO \end{matrix}\right\}$$

See the account of the constitution of the hyposulphites, page 160. Gmelin ascribes to this salt (*Handbuch der Chemie*, Band vi., 423,) the formula $C^{32}N^2H^{12}O^4S^2$, adding the authority of Erdmann and Laurent; but I imagine that this is an error in quoting the figures; otherwise we should have the simple formula:

$$ZH^3,C^8H^3; SO = \text{Indylam sulphate.}$$

Section 4.—Salts in which Sulphic-Indyl is the Negative Radical.

The nature of sulphic vice-radicals has been explained at page 136. The salts of sulphic-indyl have the usual characters of such radicals. They are all double salts if viewed in relation to their analytical formulæ and bibasic salts in accordance with their synoptical formulæ.

Analytical Formula. Synoptical Formula.

$$52]. \left\{\begin{matrix} ZH^4; C^8H^2SO^3 \\ ZH^4; S \quad O^2 \end{matrix}\right\} = ZH^4; ZH^4; C^8H^2S^2O^5.$$

Ammona sulphic-indylite cum ammona sulphete. = Ammona ammona indylsulphenute.

52]. $ZH^4; ZH^4; C^8H^2S^2O^5$ = Ammona ammona indylsulphenute.
53]. $K; ZH^4; C^8H^2S^2O^5$ = Potassa ammona indylsulphenute.
54]. $K; ZH^4; C^8HClS^2O^5$ = Potassa ammona chloric-indylsulphenute.
55]. $K; ZH^4; C^8Cl^2S^2O^5$ = Potassa ammona chlorenic-indylsulphenute.
56]. $K; ZH^4; C^8Br^2S^2O^5$ = Potassa ammona bromenic-indylsulphenute.

$$57]. \left\{\begin{matrix} \left\{\begin{matrix} ZH^2; \quad C^8H^2SO^3 \\ ZH^3, C^8H^3; \quad SO^2 \end{matrix}\right\} = \text{Amida sulphic-indylite cum indylam sulphete.} \\ = ZH^2; ZH^3,C^8H^3; C^8H^2S^2O^5 = \text{Amida indylam indylsulphenute.} \end{matrix}\right.$$

$$58]. \left\{\begin{matrix} \left\{\begin{matrix} ZHK \quad ; C^8H^2SO^3 \\ ZH^3,C^8H^3; \quad SO^2 \end{matrix}\right\} = \text{Potassac sulphic-indylite cum indylam sulphete.} \\ = ZHK; ZH^3,C^8H^3; C^8H^2S^2O^5 = \text{Potassac indylam indylsulphenute.} \end{matrix}\right.$$

52]. ZH^4; ZH^4; $C^8H^2S^2O^5$ = Ammona ammona indylsulphenute.

The ordinary names and formulæ of this salt are as follow:—Isatosulphite of ammonia = $C^{16}H^6(NH^4)NO^6,2SO^2$, *Gerhardt*. Isatinschwefligsaures ammoniak = $C^{16}NH^6(NH^4)O^6,2SO^2$, *Gmelin*. The Isatinosulphites are formulated by several chemists thus: $C^{16}H^5NO^4,2SO^2 + MO$. But this formula is deficient of HO.

53]. K; ZH^4; $C^8H^2S^2O^5$ = Potassa ammona indylsulphenute.

This is the potash-salt corresponding to the ammonia-salt No. 52]. Common names and formulæ: The isatinosulphite of potash = $C^{16}H^6KNO^6$, $2SO^2$, *Gerhardt*. Isatinschwefligsaures kali = $C^{16}NH^6,KO^6,2SO^2$, *Gmelin*. This salt occurs with water of crystallization, which can be driven off by heat; but it is also possible to drive off so much of it that the salt 53] becomes reduced to the salt 49]. Hence these two salts are frequently confounded in chemical works. The Isatinosulphurous acid, which would correspond to salts 52] and 53], is unknown. Gmelin gives its formula as $C^{16}NH^7S^2O^{10} = C^{16}NH^7O^6,2SO^2$, which would correspond to the following:

H; ZH^4; $C^8H^2S^2O^5$ = Hydra ammona indylsulphenute.

54]. K; ZH^4; $C^8HClS^2O^5$ = Potassa ammona chloric-indylsulphenute.

55]. K; ZH^4; $C^8Cl^2S^2O^5$ = Potassa ammona chlorenic-indylsulphenute.

56]. K; ZH^4; $C^8Br^2S^2O^5$ = Potassa ammona bromenic-indylsulphenute.

These three salts differ from 53] by having the hydrogen of the indyl partly replaced by chlorine and bromine as well as by sulphur. In 55] and 56] the hydrogen of the radical is entirely replaced. The vice-radicals of the four salts are as follow:

53]. C^8H^2S = Sulphic-indyl.
54]. C^8HClS = Chloric-sulphindyl.
55]. C^8Cl^2S = Chlorenic-sulphindyl
56]. C^8Br^2S = Bromenic-sulphindyl.

These salts afford remarkable examples of the great substitution that can take place in radicals, without disturbing the structure of their salts.

The ordinary name of No. 54] is the Chlorisatinsulphite of potash; of No. 55] the Bichlorisatinsulphite of potash; and of No. 56] the Bibromisatinsulphite of potash.

Hence, the ordinary names of the salts from No. 52] to 56] are quite erroneous. A *sulphite* contains $S^2 + O^4$; but these salts contain $S^2 + O^5$, and they are evidently double sulphates, including that additional atom of oxygen which always accompanies a sulphic vice-radical.

Each salt may receive a systematic name either according to the analytical or the synoptical formula, as is shown at No. 52].

$$\begin{array}{cccc} & \text{Analytical Formula.} & & \text{Synoptical Formula.} \\ 57]. & \left\{\begin{array}{lr} ZH^2, \quad ; & C^8H^2SO^3 \\ ZH^3,C^8H^3 ; & SO^2 \end{array}\right\} & = & \left\{ZH^2 ; ZH^3,C^8H^3 ; C^8H^2S^2O^5.\right. \\ & \left.\begin{array}{c} \text{Amida sulphic-indylite cum} \\ \text{indylam sulphete.} \end{array}\right\} & = & \left\{\text{Amida indylam indylsulphenute.}\right. \end{array}$$

This salt is produced when indigo blue is stirred up with dilute sulphuric acid, with free access of atmospheric air. It has received the following names: Sulphopurpuric acid; Sulphophenicic acid; Indigpurpur; Purpurschwefelsäure. Formulæ: $HO,C^{32}H^9N^2O^3,2SO^3$, *Dumas.* $C^{32}H^{10}N^2O^4,S^2O^6$, *Gerhardt.*

58]. $ZHK ; ZH^3,C^8H^3 ; C^8H^2S^2O^5$. Potassac indylam indylsulphenute.

This is the potash-salt of the so-called "acid" No. 57]. The two compounds differ only in the circumstance that the radical Amida in 57] is converted into Potassac in 58]. This substitution is effected by means of caustic potash, thus: $ZH^2 + KHO = ZHK + HHO$.

I have omitted from the preceding Table the compounds called Indine, Hydrinden, and their derivatives. The composition commonly ascribed to these compounds is such as does not admit of reduction to exact formulæ. For Indine we have $C^{16}H^6NO^2$ and $C^{16}H^5NO^2$, one corresponding to indigo blue, and the other to indigo white. For Hydrindine we have $C^{32}H^{13}N^2O^5$ and $C^{64}H^{22}N^4O^{10}$. All these are given by Laurent. The compounds that contain bromine and chlorine are equally uncertain. I have also omitted Indelibrom for a like reason.

Aniline.

The compounds of aniline are to be reckoned by hundreds; but they are not the subjects of manufacture; they are not articles of commerce; they are of no use in the arts; they are applied to no purpose in domestic economy; yet they have been the principal subject of discussion in all the chemical journals of Europe for nearly twelve years.

The reason that these compounds have commanded so much of the attention of chemists is, that they seemed to promise to afford information which would lead to the solution of the great theoretical problem which is expressed in the inquiry—*What is the nature of the Azotic Bases?* That problem is of the very highest importance, because it is impossible to make any decisive advances in physiological chemistry until chemists obtain clearer notions than have hitherto prevailed respecting the nature and functions of the compounds of azote. The researches of Hofmann, carried out with admirable experimental dexterity, have supplied a multitude of facts to aid in the solution of this problem. Yet, notwithstanding his labours, and those of many other chemists in this field, it cannot be said that the work in question has been accomplished, and that the problem of the constitution of the azotic bases has been logically solved. For that reason I take leave to call the attention of chemists to a series of arguments, which constitute one more attempt to clear away the difficulties which beset this question.

The "ANILINE THEORY," which I have to propose for the adoption of chemists, is briefly as follows: *a*). The Radical of these compounds is PHENYL = C^6H^5, which frequently undergoes substitution, and becomes chloric-phenyl = C^6H^4Cl, chlorenic-phenyl = $C^6H^3Cl^2$; bromic-phenyl = C^6H^4Br, bromenic-phenyl = C^6H^3Br; iodic-phenyl = C^6H^4I, &c. *b*). In combination with azote and hydrogen, phenyl and the vice-phenyls produce the radicals phenylac = ZH,C^6H^5, phenylam = ZH^3,C^6H^5, phenylem = $ZH^2,(C^6H^5)^2$; and the vice-phenylacs and vice-phenylams which result from the substitution of chloric-, bromic-, or iodic-phenyl for normal phenyl in such compounds. *c*). These vice-amids and vice-ammons which, it is apparent, are part of the great system of vice-amids and vice-ammons, and are in no respect peculiar to aniline, form salts by combining, in the usual way, with negative radicals of every description, oxidised or not oxidised; so that, in this respect also, they have no property peculiar to aniline, but act exactly like all other azotic radicals. *d*). The salts of these compound radicals have a great tendency to form double salts, especially salts which contain on the one part an amid and on the other part an ammon. *e*). They also possess, and frequently exercise, the power to produce triple and quadruple salts.

In this "theory" there is nothing improbable. The properties ascribed to the aniline radicals, and the structure of their double and triple salts, are such as are common to many other radicals and their salts. The pretensions of this "theory" are, not to show that aniline is wonderfully different from all other chemical compounds, but that it is able to reduce to order and regularity a mass of facts which, as they are commonly formulated and named in chemical books, are either in confusion or helpless uncertainty. The points upon which the "theory" rests are these: The dismissal of all ammonias as "bases," and the assumption of vice-amids and vice-ammons as "basic radicals," each of these radicals, whatever its composition, being equivalent in chemical power to H^1, and exercising that power in the formation of an extensive variety of single and multiple salts. Everything else follows as a matter of course, in accordance with the general principles of the radical theory.

I proceed to adduce evidence in support of this aniline theory. It consists, first, of a Table of examples selected from the most important aniline compounds; and, secondly, of a critical account of the names, formulæ, and theories applied to the same compounds by Hofmann and other chemists. On looking over the Table, the reader will see the structure of each salt; its relation to other salts of the series, and its systematic name; and on consulting the notes he will be supplied with the means of judging whether or not the theory and nomenclature now proposed are better or worse than those against which they are put in competition.

Table of the Salts of Aniline.

1]. $ZH,C^6H^5;\ H$ = Phenylac hydra.
2]. $ZH,C^6H^4Cl;\ H$ = Chloric-phenylac hydra.
3]. $ZH,C^6H^4Br;\ H$ = Bromic-phenylac hydra.
4]. $ZH,C^6H^4I;\ H$ = Iodic-phenylac hydra.
5]. $ZH,C^6H^3Br^2;\ H$ = Bromenic-phenylac hydra.
6]. $ZC^5H^{11},C^6H^5;\ H$ = Amylic-phenylac hydra.
7]. $ZC^2H^5,C^6H^5;\ H$ = Ethylic-phenylac hydra.
8]. $ZH,\ C^6H^3Br^2;\ Br$ = Bromenic-phenylac broma.
9]. $ZH,\ C^6H^3Cl^2;\ Cl$ = Chlorenic-phenylac chlora.
10]. $ZH,\ C^6H^3Br^2;\ Cl$ = Bromenic-phenylac chlora.
11]. $ZH,\ K;\ C^6H^5$ = Potassac phenyla.
12]. $ZH^3,C^6H^5;\ Cl$ = Phenylam chlora.
13]. $ZH^3,C^6H^5;\ Br$ = Phenylam broma.
14]. $ZH^3,C^6H^5;\ I$ = Phenylam ioda.
15]. $ZH^3,C^6H^4Cl;\ Cl$ = Chloric-phenylam chlora.
16]. $ZH^3,C^6H^4Br;\ Cl$ = Bromic-phenylam chlora.
17]. $ZH^3,C^6H^4I;\ Cl$ = Iodic-phenylam chlora.
18]. $ZH^3,C^6H^4I;\ I$ = Iodic-phenylam ioda.
19]. $ZH^3,C^6H^3Br^2;Cl$ = Bromenic-phenylam chlora.
20]. $\left\{\begin{matrix} ZH^3,C^6H^4Cl;\ Cl \\ Ptc^2;\ Cl^2 \end{matrix}\right\}$ = Chloric-phenylam chlora bis platic chlora.
21]. $\left\{\begin{matrix} ZH^3,C^6H^4I;\ Cl \\ Ptc^2;\ Cl^2 \end{matrix}\right\}$ = Iodic-phenylam chlora bis platic chlora.
22]. $ZH^2,C^6H^5,Hgc;\ Cl$ = Meric-phenylam chlora.
23]. $ZH^3,C^6H^5;\ NO^3$ = Phenylam nitrite.
24]. $ZH^3,C^6H^5;\ SO^2$ = Phenylam sulphete.
25]. $ZH^2,C^6H^5,Cuc:\ SO^2$ = Cupric-phenylam sulphete.
26]. $ZH^3,C^6H^4Cl;\ SO^2$ = Chloric-phenylam sulphete.
27]. $ZH^3,C^6H^4I;\ SO^2$ = Iodic-phenylam sulphete.
28]. $\left\{\begin{matrix} \left.\begin{matrix} ZH,C^6H^5;\ SO \\ H;\ SO^2 \end{matrix}\right\} \\ =H;\ ZH,C^6H^5;\ S^2O^3 \end{matrix}\right\}$ = Hydra phenylac sulphenite.
29]. $Ag;\ ZH,C^6H^5;\ S^2O^3$ = Argenta phenylac sulphenite.

30]. $Ag; Z,C^7H^5,C^6H^5; S^2O^3$ = Argenta benzylic-phenylac sulphenite.

31]. $\left\{\begin{array}{r}ZH,C^6H^3; S^2O^3\\ ZH,C^6H^5; S^2O^3\\ H; Cy\end{array}\right\}$ = Bis phenylac sulphenite cum hydra cyana.

32]. $ZH^3,C^6H^5; PO^3$ = Phenylam phosphite.

33]. $ZH^3,C^6H^5; H^2; PO^4$ = Phenylam hydren phosphote.

34]. $(ZH^3,C^6H^5)^2; H; PO^4$ = Phenylamen hydra phosphote.

35]. $(ZH^3,C^6H^5)^2; H^2; P^2O^7$ = Phenylamen hydren phospheneze.

36]. $ZH^3,C^6H^5; CO^2$ = Phenylam carbete.

37]. $ZH^3,C^6H^4I; CO^2$ = Iodic-phenylam carbete.

38]. $ZH^3,C^6H^4Br; CO^2$ = Bromic-phenylam carbete.

39]. $\left\{\begin{array}{r}ZH^3,C^6H^4Cl; CO^2\\ H; CO^2\end{array}\right\}$ = Hydra chloric-phenylam carbenote.

40]. $ZH,C^6H^5; CO$ = Phenylac carbate.

41]. $\left\{\begin{array}{l}ZH^2,\quad CO\\ ZH,C^6H^5; CO\end{array}\right\}$ = Phenylac carbate cum amida carbate.

42]. $ZH,C^6H^5; C\,H\,O$ = Phenylac formylate.

43]. $ZH,C^6H^5; C^2H^2O$ = Phenylac succinylate.

44]. $ZH,C^6H^5; C^2H^3O$ = Phenylac acetylate.

45]. $ZH,C^6H^5; C^4H^7O$ = Phenylac butyrylate.

46]. $ZH,C^6H^5; C^5H^9O$ = Phenylac valerylate.

47]. $ZH,C^6H^5; C^7H^5O$ = Phenylac benzylate.

48]. $ZH,C^6H^5; C^8H^7O^2$ = Phenylac anisylete.

49]. $ZH,C^6H^5; C^9H^7O$ = Phenylac cinnamylate.

50]. $\left\{\begin{array}{l}\left.\begin{array}{r}ZH,C^6H^5; CO\\ H; CO^2\end{array}\right\}\\ = H; ZH,C^6H^5; C^2O^3\end{array}\right\}$ = Phenylac carbate cum hydra carbete; or Hydra phenylac carbenite.

51]. $Ba; ZH,C^6H^5; C^2O^3$ = Baryta phenylac carbenite.

52]. $\left\{\begin{array}{r}ZH^3,C^6H^5; ZH,C^6H^5; C^2O^3\\ H; ZH,C^6H^5; C^2O^3\end{array}\right\}$ = Phenylam phenylac carbenite cum hydra phenylac carbenite.

53]. $\left\{\begin{array}{l}\left.\begin{array}{r}ZH,C^6H^5; C^2H^2O\\ H; C^2H^2O^2\end{array}\right\}\\ = H; ZH,C^6H^5; (C^2H^2)^2O^3\end{array}\right\}$ = Hydra phenylac succinylenite.

54]. $ZH,C^6H^5; NO^2$ = Phenylac nitrete.

55]. $\left\{\begin{array}{r}ZH,C^6H^5; NO^2\\ H; Cl\end{array}\right\}$ = Phenylac nitrete cum hydra chlora.

56]. $\left\{\begin{array}{l}ZH,C^6H^5; NO^2\\ HPtc^2\quad; Cl^3\end{array}\right\}$ = Phenylac nitrete cum hydra platenic chlorine.

57]. $\left\{\begin{array}{r}ZH,C^6H^5; NO^2\\ 2(H; CO^2)\end{array}\right\}$ = Phenylac nitrete bis hydra carbete.

58]. $\left\{\begin{array}{r}ZH,C^6H^5; NO^2\\ H; CyO\end{array}\right\}$ = Phenylac nitrete cum hydra cyanate.

59]. $\left\{\begin{array}{r} ZH,C^6H^5;\ NO^2 \\ ZH,C^6H^5;\ NO^2 \\ H;\ Cy \end{array}\right\}$ = Bis phenylac nitrete cum hydra cyana.

60]. $\left\{\begin{array}{r} ZH,C^6H^5;\ NO^2 \\ ZH,C^6H^5;\ NO^2 \\ Cy;\ Cl \end{array}\right\}$ = Bis phenylac nitrete cum cyana chlora.

61]. $\left\{\begin{array}{r} ZH,C^6H^5;\ NO^2 \\ ZH,C^6H^5;\ NO^2 \\ Cy;\ Cl \\ Ptc^2;\ Cl^2 \end{array}\right\}$ = Bis phenylac nitrete cum cyana chlora bis platic chlora.

62]. $ZH,C^6H^5;\ Cy$ = Phenylac cyana.

63]. $\left\{\begin{array}{l} ZH,C^6H^5;\ Cy \\ ZH,C^6H^5;\ H \end{array}\right\}$ = Phenylac cyana cum phenylac hydra.

64]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ Cl \end{array}\right\}$ = Phenylac cyana cum phenylam chlora.

65]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ Br \end{array}\right\}$ = Phenylac cyana cum phenylam broma.

66]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ I \end{array}\right\}$ = Phenylac cyana cum phenylam ioda.

67]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ SO^2 \end{array}\right\}$ = Phenylac cyana cum phenylam sulphete.

68]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ NO^3 \end{array}\right\}$ = Phenylac cyana cum phenylam nitrite.

69]. $\left\{\begin{array}{l} ZH,\ C^6H^5;\ Cy \\ ZH,\ C^6H^5;\ H \\ ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5,Ag;NO^3 \end{array}\right\}$ = Bis phenylac cyana cum phenylac hydra cum argentic-phenylam nitrite.

70]. $\left\{\begin{array}{r} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ CO^2 \\ H;\ CO^2 \end{array}\right\}$ = Phenylac cyana cum hydra phenylam bicarbete.

71]. $\left\{\begin{array}{l} ZH,C^6H^4Cl;\ Cy \\ ZH,C^6H^4Cl;\ H \end{array}\right\}$ = Chloric-phenylac cyana cum chloric-phenylac hydra.

72]. $\left\{\begin{array}{l} ZH,C^6H^4Br;\ Cy \\ ZH,C^6H^4Br;\ H \end{array}\right\}$ = Bromic-phenylac cyana cum bromic-phenylac hydra.

73]. $\left\{\begin{array}{l} ZH,C^6H^4I;\ Cy \\ ZH,C^6H^4I;\ H \end{array}\right\}$ = Iodic-phenylac cyana cum iodic-phenylac hydra.

74]. $\left\{\begin{array}{l} ZH,\ C^6H^4Br;\ Cy \\ ZH^2,C^6H^4Br;\ Cl \end{array}\right\}$ = Bromic-phenylac cyana cum bromic-phenylam chlora.

75]. $\left\{\begin{array}{r} ZH,\ C^6H^5;\ Cy \\ ZH^2,C^6H^5;\ Cl \\ Ptc^2;\ Cl^2 \end{array}\right\}$ = Phenylac cyana cum phenylam chlora bis platic chlora.

76]. $\left\{\begin{array}{r} \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{ZH^3,C^6H^5; Cl} \\ \mathrm{Auc^3; Cl^3} \end{array}\right\} =$ Phenylac cyana cum phenylam chlora tris auric chlora.

77]. $\left\{\begin{array}{r} \mathrm{ZH, C^6H^4Cl; Cy} \\ \mathrm{ZH^3,C^6H^4Cl; Cl} \\ \mathrm{Ptc^2; Cl^2} \end{array}\right\} =$ Chloric-phenylac cyana cum chloric-phenylam chlora bis platic chlora.

78]. $\left\{\begin{array}{r} \mathrm{ZH, C^6H^4Br; Cy} \\ \mathrm{ZH^3,C^6H^4Br; Cl} \\ \mathrm{Ptc^2; Cl^2} \end{array}\right\} =$ Bromic-phenylac cyana cum bromic-phenylam chlora bis platic chlora.

79]. $\left\{\begin{array}{r} \mathrm{ZH\ ,C^6H^5; Cy} \\ \mathrm{ZH\ ,C^6H^5; Cy} \\ \mathrm{H; Cy} \end{array}\right\} =$ Bis phenylac cyana cum hydra cyana.

79[a]. $\left\{\begin{array}{r} \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{Cy; Cl} \end{array}\right\} =$ Bis phenylac cyana cum cyana chlora.

79[b]. $\left\{\begin{array}{r} \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{H; CyO} \end{array}\right\} =$ Bis phenylac cyana cum hydra cyanate.

80]. $\left\{\begin{array}{l} \mathrm{(ZH, C^6H^5; Cy)^3} \\ \mathrm{\ ZH, C^6H^5; H} \end{array}\right\} =$ Tris phenylac cyana cum phenylac hydra.

81]. $\mathrm{ZC\ H^3,C^6H^5; Cy}$ = Methylic-phenylac cyana.

82]. $\mathrm{ZC^2H^5,C^6H^5; Cy}$ = Ethylic-phenylac cyana.

83]. $\mathrm{ZC^5H^{11},C^6H^5; Cy}$ = Amylic-phenylac cyana.

84]. $\left\{\begin{array}{l} \mathrm{ZH, C^6H^5; Cy} \\ \mathrm{ZH^3,C^6H^5; Cy} \end{array}\right\} =$ Phenylam phenylac cyanen.

85]. $\left\{\begin{array}{l} \mathrm{ZH, C^6H^5; Cy + HCl} \\ \mathrm{ZH^3,C^6H^5; Cy + HCl} \end{array}\right\} =$ Phenylam phenylac cyanen bis hydra chlora.

86]. $\left\{\begin{array}{l} \mathrm{ZH, C^6H^5; Cy + HPtc^2Cl^3} \\ \mathrm{ZH^3,C^6H^5; Cy + HPtc^2Cl^3} \end{array}\right\} =$ Phenylam phenylac cyanen bis hydra platenic chlorine.

87]. $\left\{\begin{array}{l} \mathrm{ZH, C^6H^5; Cy + HAuc^3Cl^4} \\ \mathrm{ZH^3,C^6H^5; Cy + HAuc^3Cl^4} \end{array}\right\} =$ Phenylam phenylac cyanen bis hydra aurinic chlorone.

88]. $\left\{\begin{array}{l} \mathrm{ZH, C^6H^5; Cy + HNO^3} \\ \mathrm{ZH^3,C^6H^5; Cy + HNO^3} \end{array}\right\} =$ Phenylam phenylac cyanen bis hydra nitrite.

89]. $\mathrm{ZH^3,C^6H^5; CyO}$ = Phenylam cyanate.

90]. $\mathrm{ZH^2,C^6H^5,C^6H^5; CyO}$ = Phenylem cyanate.

91]. $\mathrm{ZH^3,C^6H^5; Cy; S^2}$ = Phenylam cyana sulphene.

92]. $\mathrm{ZH^2,C^6H^5,C^6H^5; Cy; S^2}$ = Phenylem cyana sulphene.

93]. $\left\{\begin{array}{l} \mathrm{C^6H^5,CyO} \\ \mathrm{C^6H^5,CyO} \\ \mathrm{\ H, Cy} \end{array}\right\} =$ Bis phenyla cyanate cum hydra cyana.

94]. $\left\{\begin{array}{l} \mathrm{C^6H^5,CyO} \\ \mathrm{C^6H^5,CyO} \\ \mathrm{\ Ag,Cy} \end{array}\right\} =$ Bis phenyla cyanate cum argenta cyana.

95]. $\mathrm{C^6H^5,CyO}$ = Phenyla cyanate.

96]. $$\begin{cases} \mathrm{H,CH^3O + C^6H^5 ; CyO} = \text{Hydra methylate cum phenyla cyanate.} \\ = \mathrm{H,CH^3,C^6H^5 ; CyO^2} = \text{Hydra methyla phenyla cyanete.} \end{cases}$$

97]. $$\begin{cases} \mathrm{H,C^2H^5O + C^6H^5 ; CyO} = \text{Hydra ethylate cum phenyla cyanate.} \\ \mathrm{H,C^2H^5,C^6H^5 ; CyO^2} = \text{Hydra ethyla phenyla cyanete.} \end{cases}$$

98]. $$\begin{cases} \mathrm{H,C^5H^{11}O + C^6H^5 ; CyO} = \text{Hydra amylate cum phenyla cyanate.} \\ \mathrm{H,C^5H^{11},C^6H^5 ; CyO^2} = \text{Hydra amyla phenyla cyanete.} \end{cases}$$

99]. $$\left\{ \begin{array}{c} \mathrm{C^6H^5 ; CyO} \\ \mathrm{(ZH,C^6H^5 ; Cy)^3} \end{array} \right\} = \text{Phenyla cyanate tris phenylac cyana.}$$

Critical Notes on the Salts of Aniline.

1]. $\mathrm{ZH,C^6H^5 ; H}$ = Phenylac hydra.

This is the salt that is commonly called Aniline. It is prepared by fusing hydrate of potash with isatine. See Indigo, 4]. The action is represented in the following equation:

$$\left. \begin{array}{l} \mathrm{ZH^2,C^8H^3O^2} \\ \mathrm{4K,HO} \end{array} \right\} = \left\{ \begin{array}{l} \mathrm{ZH,C^6H^5 ; H} \\ \mathrm{(KK,CO^3)^2} \\ \mathrm{H^2} \end{array} \right.$$

One atom of isatine and four atoms of hydrate of potash produce one atom of aniline, two atoms of carbonate of potash, and two atoms of hydrogen. *Hofmann*, *Memoirs of the Chemical Society* (1845), iii., 271. Many other names have been given to aniline: Kyanol, Crystalline, Benzidam, Phenylamide, Amaphenase, Phenylia. It is formulated as $\mathrm{C^{12}H^7N}$ and $\mathrm{C^{12}H^5,H^2N}$. Hofmann, acting on the presumption that aniline contained ammonia, endeavoured to prove that the composition was $\mathrm{C^{12}H^4 + NH^3}$; but he did not succeed in procuring a radical of the form $\mathrm{C^{12}H^4}$; although many of his formulæ, as will hereafter be seen, are framed on the assumption that the aniline salts contain such a radical.

It is remarkable, that in the conversion of isatine into aniline, the radical indyl = $\mathrm{C^8H^3}$ is converted into the radical phenyl = $\mathrm{C^6H^5}$; in which transformation two atoms of carbon are abstracted from, and two atoms of hydrogen are added to, the original radical. This transmutation renders it probable that chemists may hereafter be able to effect considerable changes in the composition of the organic radicals which occur as products of vegetable and animal life.

2]. $\mathrm{ZH,C^6H^4Cl ; H}$ = Chloric-phenylac hydra.

Hofmann's names: Chloraniline and Amachlophenese. His formulæ

$$= C^{12}\left\{\begin{matrix} H^6 \\ Cl \end{matrix}\right\} N = \left\{\begin{matrix} H \\ H \\ C^{12}\begin{pmatrix} H^4 \\ Cl \end{pmatrix} \end{matrix}\right\} N.$$ [1]

Prepared by acting upon chlorisatine, Indigo 11], with caustic potash:

$$\left.\begin{matrix} ZH^2,C^6H^2ClO^2 \\ 4K,HO \end{matrix}\right\} = \left\{\begin{matrix} ZH,C^6H^4Cl\,;\ H \\ (KK,CO^3)^2 \\ H^2 \end{matrix}\right.$$

The reaction is quite parallel to that which occurs when normal isatine is acted upon. See No. 1. Hofmann remarks that "the capacity of saturation of chloraniline is the same as that of aniline, although the atom of the latter is lower than that of the former by the difference of the equivalents of chlorine and hydrogen (442·65 − 12·50 = 430·15)." *Mem. Ch. Soc.* ii., 277. Of course! The capacity of saturation is the same, because phenylac and chloric-phenylac are each *one* radical, with the saturating capacity of one atom. All the vice-amids and vice-ammons, whatever their composition or atomic weight, have the saturating capacity of one volume of hydrogen.

3]. $ZH,C^6H^4Br\,;\ H$ = Bromic-phenylac hydra.

Bromaniline; Amabrophenese; Bromophenylamine = $C^{12}(H^6Br)N$

$$= \left\{\begin{matrix} H \\ H \\ C^{12}\begin{pmatrix} H^4 \\ Br \end{pmatrix} \end{matrix}\right\} N.$$ *Hofmann.*

Prepared by the action of potash on bromisatine, Indigo 13], *Hofmann.*

4]. $ZH,C^6H^4I\,;\ H$ = Iodic-phenylac hydra.

Iodaniline = $C^{12}(H^6I)N$. *Hofmann.*

5]. $ZH,C^6H^3Br^2\,;\ H$ = Bromenic-phenylac hydra.

Dibromaniline; amabrophenese; Dibromophenylamine = $C^{12}(H^5Br^2)N$

$$= \left\{\begin{matrix} H \\ H \\ C^{12}\begin{pmatrix} H^3 \\ Br^2 \end{pmatrix} \end{matrix}\right\} N.$$ *Hofmann.*

---

[1] As I must refer to many of Dr. Hofmann's formulæ, which are generally written in double or triple lines, I shall, to save room, write them in a single line, thus: $C^{12}(H^6,Cl)N$, unless there appears reason to quote them graphically.

6]. $ZC^5H^{11},C^6H^5; H$ = Amylic-phenylac hydra.
7]. $ZC^2H^5,C^6H^5; H$ = Ethylic-phenylac hydra.

These two compounds contain amidogens, in which both atoms of hydrogen are replaced by compound radicals.

Hofmann's names and formulæ for No. 6]: Amylaniline; Amylophenylamine

$$= C^{22}H^{17}N = C^{12}\left\{\begin{matrix} H^6 \\ C^{10}H^{11} \end{matrix}\right\} N = \left\{\begin{matrix} H \\ C^{10}H^{11} \\ C^{12}H^5 \end{matrix}\right\} N.$$

His names and formulæ for No. 7]: Ethylaniline; Ethylophenylamine

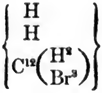
$$= C^{16}H^{11}N = C^{12}\left\{\begin{matrix} H^6 \\ C^4H^5 \end{matrix}\right\} N = \left\{\begin{matrix} H \\ C^{12}H^5 \\ C^4H^5 \end{matrix}\right\} N.$$

There exists a similar compound with CH^3, instead of C^2H^5 and C^5H^{11}, but which in other respects agrees with Nos. 6] and 7].

The compounds from No. 1] to No. 7] are commonly called "bases." They contain one atom of replaceable hydrogen. When this hydrogen is replaced by an anhydrous radical, we obtain salts with an amidogen base, such as Nos. 8] to 11]; but when the "base" combines with a "hydrated acid," the hydrogen of the "acid," added to that of the "base," is just sufficient to convert the amidogen into an ammonium. Thus, Aniline 1] = $ZH,C^6H^5; H$, with hydrochloric acid = HCl, produces hydrochlorate of aniline = $ZH^3,C^6H^5; Cl$, shown by No. 12] in the Table. The "bases" which contain chloric and bromic-phenyl act exactly in the same manner as those which contain normal phenyl; and hydrated oxygen acids act precisely like hydrochloric acid; so that it is possible to produce a great number of salts by preparing these *bases*, or hydrides of vice-amids, and then simply combining them with hydrated acids. The experimental processes are in some cases complicated; but so far as respects the theory of these compounds, nothing can be simpler. The entire aniline series consists of salts of Phenylac and Phenylam with double salts containing both of these radicals, and with a few multiple and irregular salts. The *differences* in the aniline salts depend, either upon the nature of their negative radicals, or upon certain peculiar forms of double and triple salts which admit of easy explanation. In consequence of this great regularity, I shall pass over all duplicate salts with a brief notice, and only dwell upon those prominent substances which invite critical examination. Dr. Hofmann's series of papers on aniline, in which the methods of preparation, and the properties of all the salts are described in detail, being easily accessible, in the *Quarterly Journal of the Chemical Society*, I shall not enter unnecessarily upon those subjects, but confine myself, as closely as a clear identification of the compounds will permit, to the discussion of formulæ and names.

8]. $ZH,C^6H^3Br^2; Br$ = Bromenic-phenylac broma.

Tribromaniline; amabrophenose = $C^{12}(H^4Br^3)N$.

Tribromophenylamine  N. *Hofmann.*

$$\left\{\begin{matrix} H \\ H \\ C^{12}\begin{pmatrix} H^2 \\ Br^3 \end{pmatrix} \end{matrix}\right\}N$$

This is a neutral salt, not a base; a bromide of an amidogen containing a bromenic radical.

9]. $ZH,C^6H^3Cl^2; Cl$ = Chlorenic-phenylac chlora.

Trichloraniline; amachlophenose = $C^{12}(H^4Br^3)N$, *Hofmann.* Of similar constitution to the preceding salt.

10]. $ZH,C^6H^3Br^2; Cl$ = Bromenic-phenylac chlora.

Chlorodibromaniline; amachlobrophenose = $C^{12}(H^4ClBr^2)N$, *Hofmann.*

11]. $ZH,K; C^6H^5$ = Potassac phenyla.

Anilide of potassium = $K,NH^2,C^{12}H^4$, *Hofmann.*

12]. $ZH^3,C^6H^5; Cl$ = Phenylam chlora.

Hydrochlorate of aniline = $C^{12}NH^7,HCl$, *Fritzsche.*

13]. $ZH^3,C^6H^5; Br$ = Phenylam broma.

Hydrobromate of aniline = $C^{12}H^7N,HBr$, *Hofmann.*

14]. $ZH^3,C^6H^5; I$ = Phenylam ioda.

Hydriodate of aniline = $C^{12}H^7N,HI$, *Hofmann.*

15]. $ZH^3,C^6H^4Cl; Cl$ = Chloric-phenylam chlora.

Hydrochlorate of chloraniline = $ClH,C^{12}(H^6Cl)N$, *Hofmann.*

16]. $ZH^3,C^6H^4Br; Cl$ = Bromic-phenylam chlora.

Hydrochlorate of bromaniline = $ClH,C^{12}(H^6Br)N$, *Hofmann.*

17]. $ZH^3,C^6H^4I; Cl$ = Iodic-phenylam chlora.

Hydrochlorate of iodaniline = $C^{12}(H^6I)N,HCl$, *Hofmann.*

18]. $ZH^3,C^6H^4I; I$ = Iodic-phenylam ioda.

Hydriodate of iodaniline = $C^{12}(H^6I)N,HI$, *Hofmann.*

19]. $ZH^3,C^6H^3Br^2; Cl$ = Bromenic-phenylam chlora.

Hydrochlorate of dibromaniline = $ClH,C^{12}(H^5Br^2)N$, *Hofmann.*

20]. $\left\{\begin{matrix} ZH^3,C^6H^4Cl; Cl \\ Ptc^2; Cl^2 \end{matrix}\right\}$ = Chloric-phenylam chlora bis platic chlora.

Chloraniline and bichloride of platinum = $ClH,C^{12}(H^6Cl)N + Cl^2Pt$, *Hofmann.* In this case, and in all similar cases, I use the platic atom, in order that the number of positive radicals, = Ptc^2, may equal the number of negative radicals = Cl^2, and that we may thus get rid of the necessity of assuming the existence of *bi*chlorides. See the article on the "Platinum Bases."

$$21].\ \left\{\begin{matrix} ZH^3,C^6H^4I\,;\ Cl \\ Ptc^2\,;\ Cl^2 \end{matrix}\right\} = \begin{matrix}\text{Iodic-phenylam chlora bis} \\ \text{platic chlora.}\end{matrix}$$

Bichloride of platinum and iodaniline = $C^{12}(H^6I)N,HCl + PtCl^2$, *Hofmann.*

$$22].\ ZH^2,C^6H^5,Hgc\,;\ Cl\ =\ \text{Meric-phenylam chlora.}$$

Chlorquicksilver-aniline, *Gmelin* = $C^{12}NH^7,HgCl$, *Gerhardt.* Hofmann has analysed a salt of the following constitution:

$ZH^2,C^6H^5,Hgc\,;\ Cl + 2(HgcCl)$ = Meric-phenylam chlora bis meric chlora.

$$23].\ ZH^3,C^6H^5\,;\ NO^3\ =\ \text{Phenylam nitrite.}$$

Ordinary name: Nitrate of aniline. The composition is equivalent to that of an atom of hydrated nitric acid combined with an atom of aniline; the hydrogen of these two compounds being just sufficient to convert the amidogen into an ammonium; as explained in the note to No. 7].

$$\begin{matrix} ZH,C^6H^5\,;\ H & + & HNO^3 & = & ZH^3,C^6H^5\,;\ NO^3. \\ \text{Phenylac hydra} & + & \text{Hydra nitrite} & = & \text{Phenylam nitrite.} \end{matrix}$$

The compound called Nitraniline, No. 54, is the Amide of this salt.

$$24].\ ZH^3,C^6H^5\,;\ SO^2\ =\ \text{Phenylam sulphete.}$$

Sulphate of aniline = $C^{12}NH^7,HO,SO^3$, *Zinin.* The composition is equivalent to that of a compound of an atom of hydrated sulphuric acid with an atom of aniline:

$$\begin{matrix} ZH,C^6H^5\,;\ H & + & HSO^2 & = & ZH^3,C^6H^5\,;\ SO^2. \\ \text{Phenylac hydra} & + & \text{Hydra sulphete} & = & \text{Phenylam sulphete.} \end{matrix}$$

$$25].\ ZH^2,C^6H^5,Cuc\,;\ SO^2\ =\ \text{Cupric-phenylam sulphete.}$$

Sulphate of copperoxide-aniline = $C^{12}NH^7,CuO,SO^3$, *Gmelin, Hofmann.*

$$26].\ ZH^3,C^6H^4Cl\,;\ SO^2\ =\ \text{Chloric-phenylam sulphete.}$$

Sulphate of chloraniline = $SO^3,C^{12}(H^6Cl)N + HO$, *Hofmann.* Compare the following two formulæ:

$$\begin{matrix} \text{No. 2].} & ZH,C^6H^4Cl\,;\ H \\ \text{No. 26].} & ZH^3,C^6H^4Cl\,;\ SO^2. \end{matrix}$$

Hofmann calls No. 2] Chloraniline, and No. 26] Sulphate of chloraniline, and his formulæ are:

$$C^{12}\left\{\begin{matrix}H^6\\ Cl\end{matrix}\right\}N \qquad \text{and } SO^3,C^{12}\left\{\begin{matrix}H^6\\ Cl\end{matrix}\right\}N + HO.$$

These names and formulæ effectually hide the important fact, that No. 2] is a salt of an amidogen, and No. 26] a salt of an ammonium. Such is the result of the adoption of "bases" instead of "basic radicals." They darken what they are intended to enlighten.

27]. $ZH^3,C^6H^4I ; SO^2$ = Iodic-phenylam sulphete.

Sulphate of iodaniline = $C^{12}(H^6I)N,HSO^4$, *Hofmann.*

28]. $H ; ZH,C^6H^5 ; S^2O^3$ = Hydra phenylac sulphenite.
29]. $Ag ; ZH,C^6H^5 ; S^2O^3$ = Argenta phenylac sulphenite.
30]. $Ag ; Z,C^7H^5,C^6H^5 ; S^2O^3$ = Argenta benzylic-phenylac sulphenite.

These three salts are all sulphites, and are, therefore, bibasic. See page 171. No. 28] has an atom of hydrogen replaceable by a positive radical, and on that account is called by Hofmann an "acid." No. 29] is the silver salt of that acid. No. 30] contains benzylic-phenyl in place of normal phenyl, but in other respects it is the same as No. 29]. Hofmann's formula for No. 28] is $HSO^4C^{12}H^6N,SO^2$, and his name is Sulphanilic acid. Both name and formula ignore the existence of a sulphite. Gerhardt calls it Phenyl-sulphamic acid, and gives it the formula $C^{12}H^7NS^2O^6$. Miller gives two formulæ: $HO,C^{12}H^5,HN,S^2O^5$ and $HO,C^{12}H^6NS^2O^5$. Gerhardt's name and formula for No. 30] are as follow:

$$N\left\{\begin{matrix}C^{12}H^5S^2O^4\\ C^{14}H^5O^2\\ Ag\end{matrix}\right. \quad = \quad \begin{matrix}\text{Azoture of sulphophenyle}\\ \text{of benzoile and of}\\ \text{silver.}\end{matrix}$$

By this ingenious superstructure a bibasic neutral sulphite is made to look like an ammonia. Gerhardt calls No. 29] Sulphanilate (or phenylsulphamate) of silver = $C^{12}H^6AgNS^2O^6$. Consult Azotic Radicals, No. 321], also the section on Conjugated Acids.

31]. $(ZH,C^6H^5 ; S^2O^3)^2 + HCy$ = Bis phenylac sulphenite cum hydra cyana.

According to the formula, this salt is a compound of two atoms of a hyposulphate—see page 172—with one atom of hydrocyanic acid. Hofmann gives the following account of it:—"Concentrated sulphuric acid forms with Melaniline (see No. 63) a copulated sulphuric acid, which, as it appears, possesses this remarkable composition, $C^{26}H^{13}N^3S^4O^{12}$, which crystallises, and produces soluble salts with all bases." *Supplemente zum Handwörterbuche der Chemie*, 271.

32] to 35] are phosphates of phenylam, which do not require particular notice; No. 32] is the monobasic salt. Nos. 33] and 34] are tribasic; and No. 35] is tetrabasic, or, as it is commonly called, bibasic. See page 142. They are all given on the authority of Nicholson.

36]. $ZH^3,C^6H^5 ; CO^2$ = Phenylam carbete.

Neutral oxalate of aniline = $C^2O^3,C^{12}H^7N + HO$, *Hofmann.* The composition of this salt is equal to that of an atom of hydrated oxalic acid and an atom of aniline:

$$\begin{array}{ccccc} H,CO^2 & + & ZH,C^6H^5 ; H & = & ZH^3,C^6H^5 ; CO^2. \\ \text{Hydra carbete} & + & \text{Phenylac hydra} & = & \text{Phenylam carbete.} \end{array}$$

37]. $ZH^3,C^6H^4I ; CO^2$ = Iodic-phenylam carbete.

Oxalate of iodaniline = $C^{12}(H^6I)N,HC^2O^4$, *Hofmann.*

38]. $ZH^3,C^6H^4Br ; CO^2$ = Bromic-phenylam carbete.

Oxalate of bromaniline = $C^2O^3,C^{12}(H^6Br)N,HO$, *Hofmann.*

39]. $\left\{\begin{matrix} ZH^3,C^6H^4Cl ; CO^2 \\ H ; CO^2 \end{matrix}\right\}$ = Hydra chloric-phenylam carbenote.

Binoxalate of chloraniline = $2C^2O^3,C^{12}(H^6Cl)N + HO$, *Hofmann.*

40]. $ZH,C^6H^5 ; CO$ = Phenylac carbete.

$$\left.\begin{matrix} \text{Oxanilide} = C^{12}H^6N,C^2O^2 = C^{14}H^6NO^2 \\ = NH^2,C^2O^2,C^{12}H^4 \end{matrix}\right\} \textit{Hofmann.}$$

Gerhardt's name is Diphenyl-oxamide or diazoture of diphenyle and hydrogen = $C^{14}H^{12}N^2O^2 = N^2\left\{\begin{matrix} C^2O^2 \\ (C^6H^5)^2 \\ H^2 \end{matrix}\right.$

Oxanilide is the amid of the ammonium-salt No. 36], viz.:

$$ZH^3,C^6H^5 ; CO^2 - HHO = ZH,C^6H^5 ; CO.$$

41]. $\left\{\begin{matrix} ZH,C^6H^5 ; CO \\ ZH^2 \quad ; CO \end{matrix}\right\}$ = Phenylac carbete cum amida carbete.

Oxanilamide = $C^{16}H^8N^2O^4 = C^{12}H^6N,C^2O^2 ; H^2N,C^2O^2$, *Hofmann.* A double salt containing the amid of the ammonium series and that of the phenylam series.

42]. $ZH,C^6H^5 ; CHO$ = Phenylac formylate.

Formanilide; phenyl-formiamide; azoture of phenyl, of formyl, and of hydrogen = $C^7H^7NO = N\left\{\begin{matrix} C^6H^5 \\ CHO, \\ H \end{matrix}\right.$ *Gerhardt* (*Traité de Ch.* iv. 775).

43] to 49]. For each of these seven salts Gerhardt has a pair of formulæ, and a set of three names on the model of those which I have cited in the note to No. 42]. It is useless to quote them. In all salts of this description he makes the negative radical plus the oxygen, equal in chemical power to H^1 or to C^6H^5, as against the atom of N. Now this is not accurate, because, as I am showing by hundreds of examples, the chemical powers both of H and C^6H^5 are paralysed as long as they form part of an amidogen. The power of attraction exists therefore between the negative radical with its oxygen and Z considered *with its appendage* of two radicals—as one radical; and it is quite wrong to represent H^1 and C^6H^5 as having individually in these compounds the same chemical power as the oxidised negative radical. The "type ammonia" applied in this fashion is a mere Will-o'-the-wisp, which serves only to lead one astray. See pages 209 to 214.

50]. $H;\ ZH,C^6H^5;\ C^2O^3$ = Hydra phenylac carbenite.

Oxanilic acid; phenyl-oxamic acid = $C^{16}H^7NO^6$, *Gerhardt*. Oxanilidic acid; aniloxamic acid = $HO,C^2O^3;\ C^{12}H^6N,C^2O^2 = HO,C^2\left\{\begin{matrix}O^2\\ \text{And}\end{matrix}\right.C^2O^3$, *Hofmann*. This is a double salt on the model of oxamic acid, being formed of the amide $ZH,C^6H^5;\ CO$, in combination with hydrated oxalic acid HCO^2. The hydrogen of the latter is replaceable by a metal, and it gives rise to a variety of salts of which No. 51] is a model. They are commonly called Oxanilates. See page 227.

51]. $Ba;\ ZH,C^6H^5;\ C^2O^3$ = Baryta phenylac carbenite.

There are numerous salts of similar constitution, containing ZH^4,Ag,Ca, and other positive radicals, instead of Ba. See page 227.

$$\text{52].}\ \left\{\begin{array}{l}\left.\begin{array}{r}ZH\ ,C^6H^5;\ CO\\ ZH^3,C^6H^5;\ CO^2\end{array}\right\}\\ \left.\begin{array}{r}ZH\ ,C^6H^5;\ CO\\ H\ ;\ CO^2\end{array}\right\}\end{array}\right\} = \begin{array}{l}\text{Phenylam phenylac carbenite}\\ \text{cum hydra phenylac car-}\\ \text{benite.}\end{array}$$

An inspection of the formula convinces us that this is a double or acid salt belonging to the series 50] and 51]. Acid oxanilate of aniline = $C^{16}H^6(HC^{12}H^7N)NO^6,C^{16}H^7NO^6$, *Gerhardt*. $C^{12}NH^7,2C^{16}NH^7O^6$, *Gmelin*. The formula given by Hofmann is:

$$C^{12}H^7N,HO,C^2\left\{\begin{matrix}O^2\\ \text{And}\end{matrix}\right.C^2O^3 + HO,C^2\left\{\begin{matrix}O^2\\ \text{And}\end{matrix}\right.C^2O^3$$

53]. $H;\ ZH,C^6H^5;\ (C^2H^2)^2O^3$ = Hydra phenylac succinylenite.

This compound is similar in constitution to No. 50], excepting that its acid radicals are succinyl instead of carbon. It is, of course, the amided acid that is formed by the abstraction of HHO from the bisuccinate of phenylam:

$$\left\{\begin{matrix} ZH^3,C^6H^5;\ C^2H^2O^2 \\ H^r;\ C^2H^2O^2 \end{matrix}\right\} - \left\{\begin{matrix} H,HO \\ \ \end{matrix}\right\} = \left\{\begin{matrix} ZH,C^6H^5;\ C^2H^2O \\ H^r;\ C^2H^2O^2 \end{matrix}\right\}$$

H^r is replaceable by a positive radical. See page 228. The names usually given to the salt No. 53] are Succinanilic acid, Anilo-succinamic acid, and Phenyl-succinamic acid. Formulæ: $C^{20}NH^{11}O^6 = C^{12}(C^8H^5O^2)AdH^4,O^4$, *Gmelin*. $C^8H^6(C^{12}H^5)NO^6$, *Gerhardt*.

$$C^{20}H^{11}NO^6 = HO.C^4H^2O^3;\ C^{12}H^6N,C^4H^2O^2 = HO.C^4H^2\left\{\begin{matrix} O^2 \\ And \end{matrix}\right. C^4H^2O^3,$$

Hofmann.

54]. $ZH,C^6H^5;\ NO^2$ = Phenylac nitrete.

Nitraniline = $C^{12}(H^6NO^4)N$, *Hofmann*.

55]. $\left\{\begin{matrix} ZH,C^6H^5;\ NO^2 \\ H;\ Cl \end{matrix}\right\}$ = Phenylac nitrete cum hydra chlora.

Hydrochlorate of nitraniline = $C^{12}(H^6NO^4)N,HCl$, *Hofmann*.

The formulæ which I have given to 54] and 55] differ fundamentally from those which are given to those salts by Dr. *Hofmann*. He considers nitraniline to be, like aniline, a *base*, but a base in which H^1 is replaced by NO^2. That notion would cause the formula for 54] to be $ZH,C^6H^4NO^2;\ H$; and, correspondingly, the formula for No. 55] to be $ZH^3,C^6H^4NO^2;\ Cl$. These two formulæ present to us phenyl in the condition of a vice-radical that contains NO^2 in place of H^1; the vice-phenyl forming, as usual, a phenylac and a phenylam, thus:

No. 54]. = $ZH,C^6H^4NO^2;\ H$
No. 55]. = $ZH^3,C^6H^4NO^2;\ Cl$

I consider that this method of looking at the transformation which this salt undergoes is incorrect. I will not declare that NO^2 CANNOT, *under any circumstances, form part of an amidogen or an ammonium*, but I am sceptical on the point, and I find no evidence to prove it in the case of nitraniline. On the contrary, it seems to me, that nitraniline is a neutral salt which has normal phenylac for its basic radical, and nitrogen (with O^2) for its acid radical; constituting what is commonly called a "nitrite," with the radical (ZH,C^6H^5) for its base.

Let us examine the characters of nitraniline:

"Nitraniline affords not the slightest reaction with test papers; even rose-paper, which is so exceedingly sensitive for alkalies, is not at all affected by it. . . . . Nitraniline displaces none of the metallic oxides from their acid compounds; its basic properties are exceedingly weak. Aniline displaces this base from all its salts. . . . . Although nitraniline is so weak a base, it combines with acids, affording crystallizable salts, which possess the same constitution as the corresponding salts of aniline. All its salts are decidedly acid to test papers. They are decomposed by the caustic and carbonated alkalies, nitraniline separating in a crystalline form." *Hofmann and Muspratt, Memoirs Chem. Soc.*, iii. 122.

I have formulated nitraniline as the amide which corresponds to Phenylam nitrite No. 23], namely, to the salt which, in the usual language of chemistry, is called Nitrate of aniline:

$$\text{No. 23]} = ZH^3,C^6H^5;\ NO^3 - HHO = ZH,C^6H^5;\ NO^2 = \text{No. 54]}.$$

The characteristics of nitraniline, quoted from Hofmann and Muspratt's account of it, agree precisely with such an amide. It is neutral; its combinations with acids are very acid; it cannot act as a base (a precipitant); and it is easily separated from the acids with which it combines, by any base—even by aniline.

I conclude from these particulars, that nitraniline is an amide, agreeing with the formula $ZH,C^6H^5;\ NO^2$; that it is not a base, and that there is no proof that its radical phenyl = C^6H^5, is changed into $C^6H^4NO^2$. The salts of nitraniline, Nos. 55] to 58] are consistent with these opinions. As each of them contains an atom of free hydrated acid, one can easily account for their acid reactions in accordance with the description which I have cited from Hofmann and Muspratt.

56]. $ZH,C^6H^5;\ NO^2 + HCl + 2PtcCl$ = Phenylac nitrete cum hydra chlora bis platic chlora.

Double salt of hydrochlorate of nitraniline and bichloride of platinum = $C^{12}(H^6NO^4)N,HCl,PtCl^2$, *Hofmann.*

57]. $ZH,C^6H^5;\ NO^2 + 2HCO^2$ = Phenylac nitrete bis hydra carbete.

Binoxalate of nitraniline = $C^{12}(H^6NO^4)N,HO,2(C^2O^3,HO)$, *Hofmann.*

58]. $ZH,C^6H^5;\ NO^2 + HCyO$ = Phenylac nitrete cum hydra cyanate.

This is a combination of nitraniline with hydrated cyanic acid. It is produced during the action of chloride of cyanogen on nitraniline, and subsequent treatment of the product with water. Hofmann calls it carbamide-nitrocarbanilide, and he gives it all the following formulæ: $C^{14}H^7N^3O^6 = C^{14}(H^7NO^4)N^2O^2 = NH^2,CO;\ C^{12}(H^5NO^4)N,CO$.

This compound appears to me to be precisely analogous to No. 55], and if that salt is to be supposed to contain an ammonium, this salt should also contain an ammonium; in which case 58] would be a urea—the cyanate of an ammonium, containing peroxide of nitrogen as substitute for H^1, thus: $ZH^2,C^6H^5,\ NO^2;\ CyO$. Now, I am not disposed to admit that the replacement of H in an ammonium is effected by N, or O, or NO^2, without much better evidence in support of that assumption than any that has yet been supplied. Hofmann, indeed, does not describe this compound as containing an ammonium; on the contrary, he urges our acceptance of the idea, that it is a carbamide; but there exist precisely the same objections to the admission of NO^2 into an amidogen as to its admission into an ammonium, and you can have no carbamide without a pair of amidogens—and probably none even with them. See the carbamide theory, page 221.

59]. $(ZH,C^6H^5; NO^2)^2 + HCy$ = Bis phenylac nitrete cum hydra cyana.

This salt is produced by the action of chloride of cyanogen upon nitraniline. See Hofmann, *Quarterly Journal of the Chemical Society* (1847), i. 305. Hofmann's name and formula are Dinitromelaniline $= C^{26}\left\{\begin{matrix}H^{11}\\2NO^4\end{matrix}\right\}N^3$. But his analysis shows H^{12} and not H^{11}. The experimental per centage of H was 3·96. The theoretical per centage of H^{11} is 3·65, that of H^{12} is 3·96, and that of H^{13} is 4·29. Hofmann's formula with H^{12} produces the formula: $ZH,C^6H^5; NO^2 + ZH,C^6H^5; NO^2 + Cy$. I cannot understand how Cy can be present in such a salt with no radical in combination with it, and I assume that the true quantity of H is H^{13}, which number differs no more from the experimental quantity, H^{12}, than the theoretical number, H^{11}, that was assumed by Hofmann. H^{13} gives us formula 59]. See the note to No. 60].

60]. $(ZH,C^6H^5; NO^2)^2; CyCl$ = Bis phenylac nitrete cum cyana chlora (or *cyanyl* chlora?)

This salt was prepared in the same manner as No. 59]. Hofmann's name and formula are: Hydrochlorate of dinitromelaniline

$$= C^{12}\left\{\begin{matrix}H^6\\NO^4\end{matrix}\right\}N,\ C^{12}\left\{\begin{matrix}H^5\\NO^4\end{matrix}\right\}NCy,HCl.$$

In this case Hofmann's formula agrees (in the number of ultimate atoms) with mine, which confirms the propriety of the assumption of one additional atom of hydrogen which I have made to complete the formula for No. 59].

61]. $(ZH,C^6H^5; NO^2)^2 + CyCl + 2PtcCl$ = Bis phenylac nitrete cum cyana chlora bis platic chlora.

The platinum-salt of No. 60]. Hofmann's name and formula: Bichloride of platinum and dinitromelaniline

$$= C^{12}\left\{\begin{matrix}H^6\\NO^4\end{matrix}\right\}N,\ C^{12}\left\{\begin{matrix}H^5\\NO^4\end{matrix}\right\}NCy,HCl,PtCl^2.$$

62]. $ZH,C^6H^5; Cy$ = Phenylac cyana.

Cyananilide; phenyl-cyanamide; anilide cyanique; discovered by

Cahours and Cloez = $C^{14}H^6N^2$ = $N(C^{12}H^5)CyH$, *Gerhardt*. Cyanilide = $C^{12}H^6NCy$, *Hofmann*.

63]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH, C^6H^5; H \end{matrix}\right\} =$ Phenylac cyana cum phenylac hydra.

64]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH^3, C^6H^5; Cl \end{matrix}\right\} =$ Phenylac cyana cum phenylam chlora.

65]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH^3, C^6H^5; Br \end{matrix}\right\} =$ Phenylac cyana cum phenylam broma.

66]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH^3, C^6H^5; I \end{matrix}\right\} =$ Phenylac cyana cum phenylam ioda.

67]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH^3, C^6H^5; SO^2 \end{matrix}\right\} =$ Phenylac cyana cum phenylam sulphete.

68]. $\left\{\begin{matrix} ZH, C^6H^5; Cy \\ ZH^3, C^6H^5; NO^3 \end{matrix}\right\} =$ Phenylac cyana cum phenylam nitrite.

Here are half-a-dozen double salts that exhibit great similarity in composition. Their characteristic salt is Phenylac cyana, No. 62], which occurs in all of them. The other salts of these compounds have been already described individually. No. 63] contains No. 1]; No. 64] contains No. 12]; No. 65] contains No. 13]; No. 66] contains No. 14]; No. 67] contains No. 24]; No. 68] contains No. 23.]

If we begin our examination of these compounds with No. 63], we perceive that this salt produces all the others by direct combination with hydrated acids. Thus,

No. 63] + HCl Hydrochloric acid = No. 64]
63] + HBr Hydrobromic acid = 65]
63] + HI Hydriodic acid = 66]
63] + HSO^2 Sulphuric acid = 67]
63] + HNO^3 Nitric acid. = 68].

The hydrogen in phenylac hydra added to the hydrogen of each acid is just enough to convert phenylac into phenylam, or produce an ammonium from an amidogen. See the explanatory note after No. 7].

Now let us turn to the account of those salts, that has been given by Dr. Hofmann, their discoverer. You will find it in the *Quarterly Journal of the Chemical Society* (1847), vol. i. p. 285.

No. 63] is called MELANILINE, and it is said to have these characters: "It is a new conjugated alkaloid. A conjugated base which saturates only *one* equivalent of acid. It has scarcely any action on vegetable colours. It is only slightly soluble in cold water. It dissolves easily in all acids, and with most of them forms crystallised salts. With respect to its basic properties, melaniline is nearly allied to aniline. An aniline salt cannot be decomposed by melaniline, nor has aniline any action on the salts of the other base."—*Hofmann*.

There is not one of these characters that is not perfectly consistent with the formula which I have given to the compound in No. 63]. The reason is evident why it saturates only one equivalent of acid; namely, because it contains only one replaceable atom of hydrogen. The action of vegetable colours results from the presence of the H^{1} of the aniline atom, but as the compound is only slightly soluble, the solution can have only a feeble action. Aniline has no action on salts of melaniline, because phenylac can displace neither phenylac nor phenylam.

The name melaniline was adopted in consequence of a relationship or an analogy which Dr. Hofmann supposed to exist between this body and the compound that is usually called melamine. According to my way of formulating these two compounds, they are as follow:

$$\text{Melamine} = ZH^{2},Cyl = \text{Amida cyanyla.}$$

$$\text{Melaniline} = \left\{\begin{matrix} ZH,\ C^{6}H^{5};\ Cy \\ ZH,\ C^{6}H^{5};\ H \end{matrix}\right\} = \begin{matrix}\text{Phenylac cyana cum} \\ \text{phenylac hydra.}\end{matrix}$$

The relationship that exists between these two compounds is certainly very distant; a sort of Scotch-cousinship a great many times removed.

Dr. Hofmann is, however, quite right in the following statement. "From the mode in which it is formed (viz., by the action of chloride of cyanogen on aniline) the basic atom of melaniline may be regarded as an intimate combination of aniline with cyanilide, whence the rational formula of the new compound assumes the following shape:

$$\underbrace{C^{26}H^{13}N^{3}}_{\text{Melaniline.}} = \underbrace{C^{12}H^{6}NCy,}_{\text{Cyanilide.}} \quad \underbrace{C^{12}H^{7}N.''}_{\text{Aniline.}}$$

This equation, transformed into my notation, is

$$\left.\begin{matrix} ZH,C^{6}H^{5};\ Cy \\ ZH,C^{6}H^{5};\ H \end{matrix}\right\} = ZH,C^{6}H^{5};\ Cy + ZH,C^{6}H^{5};\ H.$$

$$\text{No. 63]} = \text{No. 62]} + \text{No. 1].}$$

Hofmann's names and formulæ for the salts Nos. 64] to 68] are as follow:

64]. Hydrochlorate of melaniline = $C^{26}H^{13}N^{3},HCl$.
65]. Hydrobromate of melaniline = $C^{26}H^{13}N^{3},HBr$.
66]. Hydriodate of melaniline = $C^{26}H^{13}N^{3},HI$.
67]. Sulphate of melaniline = $C^{26}H^{13}N^{3},HSO^{4}$.
68]. Nitrate of melaniline = $C^{26}H^{13}N^{3},HNO^{6}$.

He has given another series of formulæ for these salts similar to the following example:

$$\text{No. 64]} = C^{12}H^{7}N,C^{12}H^{6}NCy,HCl.$$

For melaniline, No. 63], he has proposed the five following formulæ:

1. $C^{26}H^{13}N^{3}$.

2. $$\left.\begin{array}{l}\mathrm{H}\\ \mathrm{H}\\ \mathrm{C^{12}H^{5}}\end{array}\right\}\mathrm{N},\ \left.\begin{array}{c}\mathrm{H}\\ \mathrm{Cy}\\ \mathrm{C^{12}H^{5}}\end{array}\right\}\mathrm{N}.$$

3. $C^{12}H^{7}N,C^{12}H^{6}N,Cy$.

4. $NH^{3} + An^{2},Ad,Cy$.
where $An = C^{12}H^{4}$
$Ad = NH^{2}$.

5. $$\left.\begin{array}{c}\mathrm{(C^{12}H^{5})^{2}}\\ \mathrm{Cy}\\ \mathrm{(H^{4}N)}\end{array}\right\}\mathrm{N}.$$

$$69].\ \left\{\begin{array}{l}\left.\begin{array}{l}\mathrm{ZH,\ C^{6}H^{5};\ Cy}\\ \mathrm{ZH,\ C^{6}H^{5};\ H}\end{array}\right\}\\ \left.\begin{array}{l}\mathrm{ZH,\ C^{6}H^{5};\ Cy}\\ \mathrm{ZH^{2},C^{6}H^{5},\ \ Ag;\ NO^{3}}\end{array}\right\}\end{array}\right\} =$$ Bis phenylac cyana cum phenylac hydra cum argentic-phenylam nitrite.

This compound will be understood by comparing the formula with Nos. 63] and 68]; considering it to be a compound of these two salts, and that the radical phenylam of No. 68] is replaced in 69] by the radical argentic-phenylam; or, in other words, by supposing that two atoms of No. 63] combine with one atom of nitrate of silver, Ag,NO^{3}, to form the double or acid salt No. 69]. Hofmann's names and formulæ are: Nitrate of silver and melaniline = $2(C^{26}H^{13}N^{3}), Ag, NO^{6}$ = $2(C^{12}H^{7}N,C^{12}H^{6}NCy,),AgNO^{6}$; and, in another place, Nitrate of protoxide of silver-melaniline = $AgO,NO^{5},2C^{26}H^{13}N^{3}$. He says the composition is "somewhat uncommon." It is, however, by no means uncommon to find ammoniums that contain metallic radicals in substitution for hydrogen. It is only uncommon to find organic chemists who admit the fact that such ammoniums exist.

$$70].\ \left\{\begin{array}{r}\mathrm{ZH,\ C^{6}H^{5};\ Cy}\\ \mathrm{ZH^{3},C^{6}H^{5};\ CO^{2}}\\ \mathrm{H\ ;\ CO^{2}}\end{array}\right\} =$$ Phenylac cyana cum hydra phenylam bicarbete.

Hofmann's Binoxalate of melaniline = $C^{30}H^{15}N^{3}O^{8} = C^{26}H^{13}N^{3},HC^{2}O^{4}$, $HC^{2}O^{4} = C^{12}H^{7}N,C^{12}H^{6}NCy,2(HC^{2}O^{4})$.

$$71].\ \left\{\begin{array}{l}\mathrm{ZH,C^{6}H^{4}Cl;\ Cy}\\ \mathrm{ZH,C^{6}H^{4}Cl;\ H}\end{array}\right\} =$$ Chloric-phenylac cyana cum chloric-phenylac hydra.

Hofmann's Dichloromelaniline = $C^{26}(H^{11}Cl^{2})N^{3}$.

$$72].\ \left\{\begin{array}{l}\mathrm{ZH,C^{6}H^{4}Br;\ Cy}\\ \mathrm{ZH,C^{6}H^{4}Br;\ H}\end{array}\right\} =$$ Bromic-phenylac cyana cum bromic-phenylac hydra.

Hofmann's Dibromomelaniline = $C^{26}(H^{11}Br^{2})N^{3}$.

$$73].\ \left\{\begin{array}{l}\mathrm{ZH,C^{6}H^{4}I;\ Cy}\\ \mathrm{ZH,C^{6}H^{4}I;\ H}\end{array}\right\} =$$ Iodic-phenylac cyana cum iodic-phenylac hydra.

Hofmann's Diiodomelaniline

$$= C^{26}(H^{11}I^{2})N^{3} = C^{12}\left\{\begin{array}{l}\mathrm{H^{6}}\\ \mathrm{I}\end{array}\right\}\mathrm{N},\ C^{12}\left\{\begin{array}{l}\mathrm{H^{5}}\\ \mathrm{I}\end{array}\right\}\mathrm{NCy}.$$

Compare Nos. 71], 72], 73] with No. 63]. They agree exactly, excepting that the phenyl of 63] is replaced by chloric-, bromic-, and iodic-phenyl in the other salts. The salts remain the same in structure and in general properties.

74]. $\left.\begin{matrix} \mathrm{ZH,\ C^6H^4Br\ ;\ Cy} \\ \mathrm{ZH^3,C^6H^4Br\ ;\ Cl} \end{matrix}\right\} =$ Bromic-phenylac cyana cum bromic-phenylam chlora.

Hofmann's Hydrochlorate of dibromomelaniline = $\mathrm{C^{26}(H^{11}Br^2)N^3,HCl}$

$$= \mathrm{C^{12}}\left\{\begin{matrix}\mathrm{H^6}\\ \mathrm{Br}\end{matrix}\right\}\mathrm{N,\ C^{12}}\left\{\begin{matrix}\mathrm{H^5}\\ \mathrm{Br}\end{matrix}\right\}\mathrm{N,Cy,HCl.}$$

75]. $\left.\begin{matrix} \mathrm{ZH,\ C^6H^5\ ;\ Cy} \\ \mathrm{ZH^3,C^6H^5\ ;\ Cl} \\ \mathrm{Ptc^2\ ;\ Cl^2} \end{matrix}\right\} =$ Phenylac cyana cum phenylam chlora bis platic chlora.

Hofmann's Bichloride of platinum and melaniline = $\mathrm{C^{26}H^{13}N^3HCl,PtCl^2}$ = $\mathrm{C^{12}H^7N,C^{12}H^6NCy,HCl,PtCl^2}$.

76]. $\left.\begin{matrix} \mathrm{ZH,\ C^6H^5\ ;\ Cy} \\ \mathrm{ZH^3,C^6H^5\ ;\ Cl} \\ \mathrm{Auc^3\ ;\ Cl^3} \end{matrix}\right\} =$ Phenylac cyana cum phenylam chlora tris auric chlora.

Hofmann's Terchloride of gold and melaniline = $\mathrm{C^{26}H^{13}N^3,HCl,AuCl^3}$ = $\mathrm{C^{12}H^7N,C^{12}H^6NCy,HCl,AuCl^3}$.

77]. $\left.\begin{matrix} \mathrm{ZH,\ C^6H^4Cl\ ;\ Cy} \\ \mathrm{ZH^3,C^6H^4Cl\ ;\ Cl} \\ \mathrm{Ptc^2\ ;\ Cl^2} \end{matrix}\right\} =$ Chloric-phenylac cyana cum chloric-phenylam chlora bis platic chlora.

Hofmann's Bichloride of platinum and dichloromelaniline

$$= \mathrm{C^{26}(H^{11}Cl^2)N^3,HCl,PtCl^2} = \mathrm{C^{12}}\left\{\begin{matrix}\mathrm{H^6}\\ \mathrm{Cl}\end{matrix}\right\}\mathrm{N,\quad C^{12}}\left\{\begin{matrix}\mathrm{H^5}\\ \mathrm{Cl}\end{matrix}\right\}\mathrm{N,Cy,HCl,PtCl^2}$$

78]. $\left.\begin{matrix} \mathrm{ZH,\ C^6H^4Br\ ;\ Cy} \\ \mathrm{ZH^3,C^6H^4Br\ ;\ Cl} \\ \mathrm{Ptc^2\ ;\ Cl^2} \end{matrix}\right\} =$ Bromic-phenylac cyana cum bromic-phenylam chlora bis platic chlora.

Hofmann's Bichloride of platinum and dibromomelaniline

$$= \mathrm{C^{26}(H^{11}Br^2)\ N^3,HCl,PtCl^2} = \mathrm{C^{12}}\left\{\begin{matrix}\mathrm{H^6}\\ \mathrm{Br}\end{matrix}\right\}\mathrm{N,\ C^{12}}\left\{\begin{matrix}\mathrm{H^5}\\ \mathrm{Br}\end{matrix}\right\}\mathrm{N,Cy,HCl,PtCl^2.}$$

79]. $\left.\begin{matrix} \mathrm{ZH,C^6H^5\ ;\ Cy} \\ \mathrm{ZH,C^6H^5\ ;\ Cy} \\ \mathrm{H\ ;\ Cy} \end{matrix}\right\} =$ Bis phenylac cyana cum hydra cyana.

This salt is produced by the action of cyanogen on melaniline. Hofmann gives it the name of Dicyanomelaniline, and liberally assigns to it six different formulæ, which give us certainly the opportunity of choice, but necessarily accompanied by its embarrassments:

$$C^{30}H^{13}N^5 = Cy^2,C^{26}H^{13}N^3 = CyC^{12}H^7N;\ Cy,C^{12}H^6NCy$$

$$= C^{12}H^7N,C^{12}H^6NCy\left\{\begin{array}{l}Cy\\Cy\end{array}\right. = NH^3(2AnCy,AdCy)$$

$$= Cy\left\{\begin{array}{l}H\\H\\C^{12}H^5\end{array}\right\}N,\ Cy\left\{\begin{array}{l}H\\Cy\\C^{12}H^5\end{array}\right\}N.$$

Gmelin's name and formulæ are Bicyanmelanilin = $C^{24}Cy^3Ad^2H^7,H^2$.

Compare No. 79] with No. 63.] There really seems to be no difficulty in the matter, and no necessity to marshal such an army of formulæ. The transformation which takes place in this process is of the simplest possible character. Two atoms of cyanogen, combine with one atom of melaniline, converting H^1 from a negative into a positive radical, and producing a triple cyanide. But let us listen to Dr. Hofmann:

"In dicyanomelaniline the basic properties of melaniline are still perceptible: they appear, however, less prominent than in the descendants of substitution. The cyanogen base dissolves with great facility in dilute acids in the cold. On adding ammonia to the acid solution, a few moments after it has been made, a white precipitate is thrown down, consisting of unaltered dicyanomelaniline. I have, however, *vainly tried to prepare salts of this base.*"—*Hofmann, Quarterly Jour. Chem. Soc.* 1848, i. 309.

"I have vainly endeavoured to produce crystallized combinations of dicyanomelaniline with acids. In fact, the only experimental evidence of the basic nature of this substance is the remarkable facility with which it dissolves in mineral as well as vegetable acids."—*Idem*, 1849, ii. 307.

Those who look at formula No. 79] will feel little surprise that Dr. Hofmann should fail in preparing salts by adding *acids* to such a "base." They will feel more surprise that he should attach to the word "base" a meaning with so wide a latitude.

$$79^a].\ \left\{\begin{array}{r}ZH,C^6H^5;\ Cy\\ZH,C^6H^5;\ Cy\\Cy;\ Cl\end{array}\right\} = \begin{array}{c}\text{Bis phenylac cyana cum}\\\text{cyana chlora.}\end{array}$$

Discovered by Laurent. Chlorcyaniled; formulæ: $C^{30}N^5ClH^{12} = C^{24}Cy^3Ad^2H^7,HCl$, *Gmelin*.

$$79^b].\ \left\{\begin{array}{r}ZH,C^6H^5;\ Cy\\ZH,C^6H^5;\ Cy\\H\ ;\ CyO\end{array}\right\} = \begin{array}{c}\text{Bis phenylac cyana cum}\\\text{hydra cyanate.}\end{array}$$

Anilinammeline = $C^{30}N^5H^{13}O^2$, *Gmelin*.

$$80]. \left\{\begin{array}{l}(ZH,C^{6}H^{5};\ Cy)^{3}\\ ZH,C^{6}H^{5};\ H\end{array}\right\} = \begin{array}{c}\text{Tris phenylac cyana cum}\\ \text{phenylac hydra.}\end{array}$$

Compare with Nos. 62] and 63]. According to Hofmann, when melaniline is heated, aniline distils over, and leaves a residue that has the following composition: $C^{54}H^{25}N^{7}$; and he says, "The simplest interpretation of this formula consists in regarding it as a compound of the aniline-mellon with three equivalents of aniline.

$$\begin{array}{lll}\text{Mellon . . .} & C^{6}N^{4} & \\ \text{Aniline-mellon .} & C^{6}N^{4}(C^{12}H^{4}) & = C^{18}H^{4}N^{4}\\ & C^{54}H^{25}N^{7} & = C^{18}H^{4}N^{4} + 3C^{12}H^{7}N.\end{array}$$

"If this formula actually represents the composition of the body in question, its formation would be the result of the separation of two aniline atoms from three equivalents of melaniline.

$$\begin{array}{lcl}3C^{26}H^{13}N^{3} & = & C^{78}H^{39}N^{9}\\ 2C^{12}H^{7}\,N & = & C^{24}H^{14}N^{2}\\ \hline & & C^{54}H^{25}N^{7}."\end{array}$$

—*Quar. Jour. Chem. Soc.* ii. 323.

This conclusion is correct; but why does he go to it by so roundabout a process? What have we to do with mellon or aniline-mellon, or with $C^{6}H^{4}$, or $C^{12}H^{4}$, or $C^{18}H^{4}N^{4}$? The process and its interpretation are extremely simple, and require none of these far-fetched luminaries to enlighten them. Thus:

$$\begin{array}{cccccc} & \text{Used.} & & \text{Obtained.} & & \\ \begin{array}{c}\text{3 atoms of}\\ \text{No. 63]}\end{array} & \left\{\begin{array}{l}\left.\begin{array}{l}ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ H\end{array}\right\}\\ \left.\begin{array}{l}ZH,C^{6}H^{5};\ H\\ ZH,C^{6}H^{5};\ H\end{array}\right\}\end{array}\right. & \begin{array}{c}=\\ \\ \\ =\end{array} & \begin{array}{l}\left\{\begin{array}{l}ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ Cy\\ ZH,C^{6}H^{5};\ H\end{array}\right\}\\ \left\{\begin{array}{l}ZH,C^{6}H^{5};\ H\\ ZH,C^{6}H^{5};\ H\end{array}\right\}\end{array} & \begin{array}{c}=\\ \\ \\ =\end{array} & \begin{array}{c}\text{1 atom of}\\ \text{No. 80].}\\ \\ \text{2 atoms of}\\ \text{No. 1].}\end{array}\end{array}$$

81]. $ZCH^{3},C^{6}H^{5};\ Cy$ = Methylic-phenylac cyana.
82]. $ZC^{2}H^{5},C^{6}H^{5};\ Cy$ = Ethylic-phenylac cyana.
83]. $ZC^{5}H^{11},C^{6}H^{5};\ Cy$ = Amylic-phenylac cyana.

These salts are so simple that they require no explanation. Gerhardt's names and formulæ are as follow:—

$$81]. \left\{\begin{array}{l}\text{Methyl-phenyl-cyanamide, or}\\ \quad\text{cyanic methylanilide}\end{array}\right\} C^{8}H^{8}N^{2} = N \left\{\begin{array}{l}CH^{3}\\ C^{6}H^{5}\\ Cy\end{array}\right.$$

$$82]. \left\{\begin{array}{l}\text{Ethyl-phenyl-cyanamide, or}\\ \quad\text{cyanic ethylanilide}\end{array}\right\} C^{9}H^{10}N^{2} = N \left\{\begin{array}{l}C^{2}H^{5}\\ C^{6}H^{5}\\ Cy\end{array}\right.$$

$$83].\ \left\{\begin{array}{l}\text{Amyl-phenyl-cyanamide, or}\\ \quad\text{cyanic amylanilide}\end{array}\right\} C^{12}H^{16}N^{2} = N\left\{\begin{array}{l}C^{5}H^{11}\\ C^{6}H^{5}\\ \ Cy\end{array}\right.$$

These three formulæ exhibit the usual excellencies of Gerhardt's " type ammonia," and make simple things complex with remarkable facility. We are here called upon to believe (if we can) that cyanogen can replace hydrogen in ammonia, and that the result is still an ammonia.

$$84].\ \left\{\begin{array}{l}ZH\ ,C^{6}H^{5};\ Cy\\ ZH^{2},C^{6}H^{5};\ Cy\end{array}\right\} = \text{Phenylam phenylac cyanen.}$$

This formula is intended to represent the compound which Dr. Hofmann calls Cyaniline, and which he represents by the following formulæ: $C^{14}H^{7}N^{2} = Cy,C^{12}H^{7}N$.

According to Dr. Hofmann's opinion, cyaniline is formed by the direct union of one equivalent of aniline and one equivalent of cyanogen. Those materials produce $ZH,C^{6}H^{5}; H + Cy$. But this formula represents the radical phenylac in combination at once with two different radicals, H and Cy. To overcome this irregularity, I double the formula, which produces No. 84], a double salt which is quite in accordance with many other salts of phenylac. See Nos. 64] to 70]. The solutions of cyaniline are perfectly neutral, and the compound resembles a neutral salt much more than it does a base.

85] to 88]. These formulæ represent examples of the compound salts which are formed by cyaniline. This compound combines both with hydrated acids and with the metallic chlorides, and always in such a manner that the phenylac cyana and phenylam cyana are both combined with the hydrated acid and the chloride. These relations are shown by the formulæ.

These compounds are prepared with difficulty, because cyaniline is readily decomposed by water. " The constitution of the salts of cyaniline," says Hofmann, " is similar to that of the aniline salts. These compounds are, in fact, aniline salts, which have become *associated with the elements of cyanogen*. I have, however, vainly tried to obtain a salt of cyaniline by passing a current of cyanogen gas into an alcoholic solution of an aniline salt."

If, in accordance with Dr. Hofmann's opinion, we formulate the salts of cyaniline so as to be similar to the salts of aniline with cyanogen as an adjunct, "associated," as he calls it, which I understand to mean, not combined, but *hanging on loosely*, they will appear as follows:—

85]. $ZH^{2},C^{6}H^{5}; Cl + Cy$.
86]. $ZH^{2},C^{6}H^{5}; Cl + 2PtcCl + Cy$.
87]. $ZH^{2},C^{6}H^{5}; Cl + 3AucCl + Cy$.
88]. $ZH^{2},C^{6}H^{5}; NO^{3} + Cy$.

The hydrogen of the hydrated acids is just enough to convert the phenylac into phenylam, and this simplifies the formula greatly. But what is the function of the cyanogen in these salts after the hydrated acids have converted them into salts of phenylam? Is this a case where we have *biacid* salts; or is the cyanogen, as Hofmann assumes, a "copula," an unexplained and unexplainable adjunct of the phenylam? "The formation of this base," he says, "offers one of the first instances in which an organic alkali is found associated with another compound, the presence of which does not affect its saturating capacity." What gives chlorine the power in these special cases, and only in these special cases, to nullify the saturating capacity of cyanogen? Upon the whole, I am of opinion, that it is safest to consider these compounds as quadruple salts, such as they are exhibited by formulæ Nos. 85] to 88], page 279. The assumptions of Dr. Hofmann lead to consequences that are too important to be admitted without sufficient evidence. I cannot understand the position of an "associated" radical, which has no functions to perform. That is not according to the common course of nature, which makes every atom do its duty.

89]. $ZH^3,C^6H^5; CyO$ = Phenylam cyanate.

Hofmann's Carbamide-carbanilide, or Anilo-urea. Procured by the action of hydrated cyanic acid = $HCyO$ upon aniline = $ZH,C^6H^5; H$.

90]. $ZH^2,C^6H^5,C^6H^5; CyO$ = Phenylem cyanate.

Hofmann's Carbanilide.

These two compounds belong to the class of *Ureas*, that is to say, each of them is a cyanate of an ammonium; and they differ from one another only in the circumstance, that the radical phenylem of No. 90] contains twice as much phenyl as is contained in the radical phenylam of No. 89]. Nevertheless, these two salts form the subject of a special theory by Dr. Hofmann, and as I consider that that theory is fallacious, I shall quote his arguments in full.

"The method by means of which I first obtained anilo-urea, viz., the action of hydrated cyanic acid on aniline, very naturally suggested the idea that this compound must be considered as an analogue of urea; as urea containing the elements $C^{12}H^4$.

Urea . . . . . . $NH^3HC^2NO^2$,
Anilo-urea . $(C^{12}H^4)NH^3HC^2NO^2$,

and hence the name under which I have described it.

"This mode of regarding it is, however, not supported by the chemical deportment of the compound; in anilo-urea we no longer find a remnant of basic properties. [1] I have vainly endeavoured to combine it with acids, in order to produce compounds analogous to nitrate or oxalate of urea. The presence of these acids does not increase the solubility of the aniline compound in water, and the crystals deposited on cooling retain no acid. My attempts to form a platinum-salt have likewise been unsuccessful. [2].

"The formula of anilo-urea admits, however, of another interpretation, which is strikingly supported by experimental evidence. The following equation:

$$C^{14}H^{8}N^{2}O^{2} = NH^{2},CO; C^{12}H^{6}N,CO,$$

shows that we may consider this substance, likewise, as a double compound of carbamide with its conjugated analogue. The existence of such double compounds is by no means isolated: in a Memoir on the Metamorphoses of Cyaniline, which I intend shortly to present to the Society, I shall have to describe a body of perfectly similar construction, viz., a compound of oxamide with oxanilide, corresponding in every respect to the preceding substance. [3].

Carbamide-carbanilide	$NH^{2},CO ; C^{12}H^{6}N,CO$.
Oxamide-oxanilide	$NH^{2},C^{2}O^{2} ; C^{12}H^{6}N,C^{2}O^{2}$.

I was very curious to submit this idea to the test of experiment, and was fortunate enough to meet with a reaction, which leaves little doubt regarding the structure of anilo-urea, or carbamide-carbanilide, as the substance more properly should be called. I found that, when submitted to the action of heat, this compound actually splits into its proximate constituents; one of which, the carbanilide, is the principal product of the reaction, whilst the other, unable to exist at the temperature at which the separation takes place, undergoes a further metamorphosis, and can be recognized only in its derivatives.

"In submitting anilo-urea to the action of heat, the substance fuses without decomposition; on increasing, however, the temperature above the fusing-point, torrents of ammonia are evolved, while the liquid in the retort solidifies to a crystalline mass, which again liquifies, and ultimately distils on a further elevation of the temperature. If the process be interrupted as soon as the evolution of ammonia ceases, and the solid begins to liquefy again, the residue in the retort consists of carbanilide and cyanuric acid. On treating this mixture with a large quantity of boiling water, the whole of the cyanuric acid, together with a small quantity of the other substance, is dissolved. In order to obtain the cyanuric acid, the aqueous solution is evaporated to dryness, and the residue extracted with alcohol, when carbanilide is dissolved, and the acid remains in a state of purity. The properties of cyanuric acid are so marked, that I have omitted to analyse the product; its comportment with solvents, and emitting also the well-known odour of cyanic acid when heated, appearing quite sufficient to obviate all chance of mistake.

"The production of carbanilide, of ammonia, and of cyanuric acid in this reaction, admits of an easy explanation, if we recollect that carbamide is actually a submultiple of urea, which, as is well known, when submitted to dry distillation, is converted into ammonia and cyanuric acid.

"Two equivalents of the compound contain the elements of two equivalents of carbanilide and one of urea: [4]

$$\underbrace{2C^{14}H^8N^2O^2}_{\substack{\text{Carbamide-}\\ \text{Carbanilide.}}} = \underset{\text{Carbanilide.}}{2C^{13}H^6NO} + \underset{\text{Urea:}}{C^2N^2H^4O^2},$$

and the following equation exhibits the final results of the destruction of carbamide-carbanilide by heat [5]:

$$\underbrace{6C^{14}H^8N^2O^2}_{\substack{\text{Carbamide-}\\ \text{Carbanilide.}}} = 3NH^3 + \underbrace{6C^{13}H^6NO}_{\text{Carbanilide.}} + \underset{\text{Cyanuric acid.}}{H^3,C^6N^3O^6}.$$

"The substance which I have described in the preceding pages claims some interest, as the first conjugated amide which was discovered, and as the first member of a class of compounds which has been enriched in so remarkable a manner by the investigations of MM. Gerhardt and Laurent."—*Quarterly Journal of the Chemical Society*, 1848, ii., 42.

Remarks on the above statement.—1] Anilo-urea is a neutral salt and not a base; and it has no replaceable hydrogen, except what constitutes the ammonium. Why should it have "a remnant of basic properties?"

2]. The so-called salts of ordinary urea are not normal salts formed by a base with an acid, but double salts containing two complete single salts. It is not necessary that every urea should form double salts.

3]. These two salts are, as I view them, not perfectly *similar*, but perfectly *dissimilar*. Just double the atomic weight of the carbon and oxygen, and then examine how the two compounds are individually affected by that simple operation, which, remember, is not a special operation suggested for this occasion, but one to which all compounds are made to submit, when brought under the rule of the radical theory. The compounds are then:

$$\begin{array}{ll} NH^2 & ;\ C^{12}H^6N,CO. \\ NH^2,CO & ;\ C^{12}H^6N,CO. \end{array}$$

The second compound is No. 41] in the above Table. The first compound is No. 89]. Surely there is no "perfect similarity" here? The difference in the relative quantities of C and O, in the two compounds, is a difference which produces a perfect *dissimilarity* in the compounds. No. 41] *can* be a double oxamide; No. 89] *cannot*, because of the absence of the necessary quantity of CO. No. 89] *can* be a cyanate, having the necessary ingredients in the necessary preparations. No. 41] *cannot* be a cyanate, because of the unsuitableness of the proportions of its constituents.

4]. Even this short equation is more explicit when made according to the radical theory. Two atoms of No. 89 produce one atom of No. 90, and one of urea = ammona cyanate ZH^4,CyO. Thus:

$$\left.\begin{array}{l}ZH^3,C^6H^5;\ CyO\\ ZH^3,C^6H^5;\ CyO\end{array}\right\} = \left\{\begin{array}{ll}ZH^2,(C^6H^5)^2; & CyO.\\ ZH^4 & ;\ CyO.\end{array}\right.$$

5]. The following diagram shows the final results of the decomposition. Thus exhibited, these results support the Urea theory, and are adverse to Dr. Hofmann's opinions:

$$\begin{array}{ccl}\text{Acted upon.} & & \text{Produced.}\\ \left.\begin{array}{l}ZH^3,C^6H^5;\ CyO\\ ZH^3,C^6H^5;\ CyO\end{array}\right\} & = & \left\{\begin{array}{l}ZH^2,\ C^6H^5,C^6H^5;\ CyO\\ ZH^2;\ H\\ \quad H;\ CyIO\end{array}\right.\end{array}$$

Thus, two atoms of 89] Phenylam cyanate, produce one atom of 90] Phenylem cyanate, one atom of ammonia, and one atom of cyanuric acid. I conclude therefore that the salts 89] and 90] are *not* examples of "conjugated amides," and that the terms carbamide-carbanilide and carbanilide convey views that are erroneous. The urea theory is much simpler and more probable, and IS SUPPORTED, though Dr. Hofmann thinks otherwise, by the chemical deportment of each of the compounds.

"Aniline, when introduced into an atmosphere of phosgene gas, solidifies at once into a crystalline mixture of carbanilide and hydrochlorate of aniline:

"$2C^{12}H^7N + COCl = C^{12}H^7N,HCl + C^{12}H^6N,CO$."—*Hofmann.*

I prefer the following equation:

$$\begin{array}{ccl}\text{Used.} & & \text{Produced.}\\ \left.\begin{array}{l}4(ZH,C^6H^5;\ H)\\ \quad CCl,ClO\end{array}\right\} & = & \left\{\begin{array}{l}ZH^2,C^6H^5,C^6H^5;\ CNO\\ 2(ZH^3,C^6H^5;\ Cl).\end{array}\right.\end{array}$$

91]. $ZH^3,C^6H^5 \quad ;\ Cy;\ S^2$ = Phenylam cyana sulphene.
92]. $ZH^2,C^6H^5,C^6H^5;\ Cy;\ S^2$ = Phenylem cyana sulphene.

On a comparison of the formulæ Nos. 91] and 92] with Nos. 89] and 90], it will be perceived that these salts exactly correspond to one another. No. 91] is the sulphocyanide of phenylam, and No. 92] is the sulphocyanide of phenylem.

Dr. Hofmann's name for No. 91] is Hydrosulphocyanate of aniline, and his formula is $C^{12}H^7N,HC^2NS^2$. His name for No. 92] is Sulphocarbanilide, and his formula is $C^{12}H^6N,CS$. The first formula, after doubling the atomic weight of the carbon, agrees with No. 91]; but, on account of the odd atom of carbon in the last formula, I must double the whole formula, which then agrees with No. 92].

The compound No. 92] can be procured by the action of aniline on bisulphide of carbon; thus:

$$\text{No. 1.} = \left\{\begin{array}{r} ZH,C^{6}H^{5};\ H \\ ZH,C^{6}H^{5};\ H \\ CS^{4} \end{array}\right\} = \left\{\begin{array}{r} ZH^{2},C^{6}H^{5},C^{6}H^{5};\ CN;\ S^{2} = \text{No. 92.} \\ H;\ S \qquad\qquad \\ H;\ S \qquad\qquad \end{array}\right.$$

METAMORPHOSES OF DICYANOMELANILINE.—"The products arising from the decomposition of dicyanomelaniline (No. 79) belong to the most remarkable substances which have been brought to light by this investigation" [*i. e.* of aniline and its derivatives], *Hofmann.* For this reason I will add a short account of these products:—

$$93].\ \left\{\begin{array}{c} C^{6}H^{5},CyO \\ C^{6}H^{5},CyO \\ H\ ,Cy \end{array}\right\} = \begin{array}{l}\text{Bis phenyla cyanate cum} \\ \quad\text{hydra cyana.}\end{array}$$

The formula of dicyanomelaniline is given at No. 79]. It is:

$$(ZH,C^{6}H^{5};\ Cy)^{2} + HCy.$$

a). When dicyanomelaniline was heated with hydrochloric acid, it produced a considerable quantity of chloride of ammonium, and a new salt which Dr. Hofmann calls Melanoximide or Oxamelanile, and which proved on analysis to have the following composition (in Hofmann's numbers): $C^{30}H^{11}N^{3}O^{4}$. "This formula," he says, "readily explains the transformation of dicyanomelaniline under the influence of acids. One equivalent of this substance assimilates four equivalents of water, while two equivalents of ammonia combine with the acid.

$$\underbrace{C^{30}H^{13}N^{5}}_{\substack{\text{Dicyano-}\\ \text{melaniline.}}} + 4HO + 2HCl = \underbrace{C^{30}H^{11}N^{3}O^{4}}_{\text{Melanoximide.}} + 2H^{4}NCl.$$

b). "This determination leaves no doubt respecting the composition of the new substance, and this is moreover supported by various phenomena of transformation which I shall describe hereafter. The formula derived from analysis, although correctly enumerating the elements grouped in the compound, leaves us quite in the dark respecting their actual arrangement, and consequently of the position which has to be assigned to the substance.

c). "A rational interpretation of the analysis was, however, greatly facilitated by the previous study of the decomposition of cyaniline. The conversion of this substance into oxalates of aniline and ammonia, or rather into compounds derived from those salts by elimination of water, (oxanilide and oxamide,) at once gave the clue to the nature of the Melanoximide. It may be considered as binoxalate of melaniline, less four equivalents of water:

$$\begin{array}{rcl}
C^{26}H^{13}N^{3},HC^{2}O^{4} + HC^{2}O^{4} & = & C^{30}H^{15}N^{3}O^{8} \\
\underbrace{C^{30}H^{15}N^{3}O^{8}}_{\text{Binoxalate of Melaniline.}} - 4HO & = & \underbrace{C^{30}H^{11}N^{3}O^{4}}_{\text{Melanoximide.}}
\end{array}$$

d). "Experiment supports this view in an unequivocal manner. On adding ammonia or potash to an alcoholic solution of the compound, the liquid readily solidifies into a crystalline mass. These crystals are melaniline; the mother liquor contains a considerable proportion of oxalic acid."—*Quarterly Journal of the Chemical Society*, ii. 310.

From these experiments Dr. Hofmann draws the conclusion that the substance under examination is what, in an ammonia series, would be called an Imide, and in the aniline series is an Anile; *i. e.*, the "binoxalate of melaniline *less* 4 *equivalents of water*." I venture to show the reader that the conclusions to which we are led by the radical theory, though very different from these, are far simpler and more probable. I shall explain the first reaction (*a*) by an equation:

$$\begin{array}{rl}
 & \text{Used.} \\
79]. & \left\{\begin{array}{r} ZH,C^{6}H^{5}\,;\ CN \\ ZH,C^{6}H^{5}\,;\ CN \\ H,\ \ CN \end{array}\right. \\
\begin{array}{c}\text{Hydrochoric} \\ \text{Acid}\end{array} & \left\{\begin{array}{l} H,Cl \\ H,Cl \end{array}\right. \\
\text{Water} & \left\{\begin{array}{l} H,HO \\ H,HO \end{array}\right.
\end{array}\right\} = \left\{\begin{array}{ll}
 & \text{Produced.} \\
\left.\begin{array}{l} C^{6}H^{5},CNO \\ C^{6}H^{5},CNO \\ \ \ H,\ CN \end{array}\right\} & \begin{array}{c}\text{No. 93].} \\ \text{Melanoximide} \\ = C^{15}H^{11}N^{3}O^{2}.\end{array} \\
\left.\begin{array}{l} ZH^{4},\ Cl \\ ZH^{4},\ Cl \end{array}\right\} & \begin{array}{c}\text{Chloride of} \\ \text{Ammonium.}\end{array}
\end{array}\right.$$

Here we have the whole process completely developed. There is no evidence that binoxalate of melaniline is first formed and then decomposed to produce the new compound; nor is it necessary to resort to such an assumption, nor to imagine that we have to deal either with an Imide or an Anile. The salt 93] appears to be a compound of two atoms of cyanate of phenyl and one atom of hydrocyanic acid. The predisposing cause of the decomposition of the dicyanomelaniline is, probably, that the two atoms of Z, in the presence of Cl and of abundance of H, exercise their usual function of enlarging their amidogens to ammoniums. These ammoniums might be expected to include the phenyl that is present in the salt under decomposition; but they do not, and we may reasonably infer thence, that the attachment of the phenyl to the cyanogen prevents it. I have shown in other cases (see 85] to 88]) the probability that phenylic radicals can combine with cyanogen in preference to chlorine, and in the presence of chlorides. I do not agree with Dr. Hofmann, that we are "quite in the dark respecting the actual arrangement of the elements in this compound," because his own experiments make the grouping of the constituent salts tolerably clear.

The experiment described in paragraph *d*) is perfectly in accordance with the above explanation, and may be stated in an equation as follows:

$$93]. \quad \begin{array}{r} \\ \\ \\ \text{Caustic} \\ \text{potash} \end{array} \left\{\begin{array}{c} C^6H^5,CNO \\ C^6H^5,CNO \\ H,\ CN \\ K,HO \\ K,HO \end{array}\right\} = \left\{\begin{array}{l} \left.\begin{array}{l} ZH,C^6H^5;\ CN \\ ZH,C^6H^5;\ H \end{array}\right\} \text{Melaniline.} \\ \\ \left.\begin{array}{c} K,CO^2 \\ K,CO^2 \end{array}\right\} \begin{array}{c} \text{Oxalate of} \\ \text{potash.} \end{array} \end{array}\right.$$

$$94]. \quad \left\{\begin{array}{c} (C^6H^5,CyO)^2 \\ Ag,Cy \end{array}\right\} \begin{array}{l} \text{Bis phenyla cyanate cum argenta} \\ \quad \text{cyana.} \end{array}$$

This salt is the silver-salt of the preceding compound, No. 93], which has merely changed its basic H for Ag. Dr. Hofmann's analysis confirms this formula, but he is in great doubt about its propriety. He says, "Several of the amidogen-compounds which have been examined, such as camphorimide and phtalimide, have the properties of weak acids: they combine, for example, with protoxide of silver. The actual nature of these combinations is scarcely understood. Some consider them as compounds of the imides with the oxides; others as imides in which hydrogen is replaced by silver; melanoximide is also feebly acid . . . . and yields a precipitate with nitrate of silver." The metallic compounds to which Dr. Hofmann alludes are the vice-radicals and vice-amids which contain substituting metals. See pages 137 and 191. His analysis leaves no doubt respecting the regularity of the salt No. 94,], which may serve as an example to convince chemists "by whom these compounds are scarcely understood," that it is quite possible to understand them perfectly, if they will take the trouble to examine the facts which prove their existence and nature.

$$95].\ C^6H^5,CyO = \text{Phenyla cyanate.}$$

This compound was produced by the action of heat on melanoximide No. 93], its relation to which is obvious at a glance. Dr. Hofmann calls it ANILOCYANIC ACID. His formula is $C^{14}H^5NO^2$. He informs us that when this compound is treated with aniline it yields carbanilide (*a*), and that when it is heated with ammonia it is converted into carbamide-carbanilide (*b*). These transformations can be readily represented by the new formulæ, thus:

$$a).\ \left\{\begin{array}{lcr} \text{No. 95]} & = & C^6H^5,CyO \\ \text{No. 1]} & = & ZH,C^6H^5;\ H \end{array}\right\} = \underbrace{ZH^2,(C^6H^5)^2;\ CyO}_{\text{Carbanilide.}} = \text{No. 90].}$$

$$b).\ \left\{\begin{array}{lcr} \text{No. 95]} & = & C^6H^5;\ CyO \\ \text{Ammonia} & = & ZH^3\qquad;\ H \end{array}\right\} = \underbrace{ZH^3,C^6H^5;\quad CyO}_{\text{Carbamide-carbanilide.}} = \text{No. 89].}$$

$$96].\ \left\{\begin{array}{l} H,CH^3O + C^6H^5,CyO = \text{Hydra methylate cum phenyla cyanate.} \\ = H,CH^3,C^6H^5;\ \ CyO^2 = \text{Hydra methyla phenyla cyanete.} \end{array}\right.$$

$$97]. \begin{cases} H,C^2H^5O+C^6H^5;CyO = \text{Hydra ethylate cum phenyla cyanate} \\ = H,C^2H^5,C^6H^5;CyO^2 = \text{Hydra ethyla phenyla cyanete.} \end{cases}$$

$$98]. \begin{cases} H,C^5H^{11}O+C^6H^5,CyO = \text{Hydra amylate cum phenyla cyanate.} \\ = H,C^5H^{11},C^6H^5;CyO^2 = \text{Hydra amyla phenyla cyanete.} \end{cases}$$

" Anilocyanic acid dissolves in the alcohols with considerable evolution of heat, clear liquids being formed, which, after some minutes, deposit magnificent crystals. I have convinced myself by analysis that the ordinary alcohols absorb one equivalent of anilocyanic acid, giving rise to the production of the following series of compounds:

Methyl-compound $C^{16}H^9NO^4 = C^2H^4O^2 + C^{14}H^5NO^2$
Ethyl-compound $C^{18}H^{11}NO^4 = C^4H^6O^2 + C^{14}H^5NO^2$
Amyl-compound $C^{24}H^{17}NO^4 = C^{10}H^{12}O^2 + O^{14}H^5NO^2$."

—Hofmann, *Quarterly Journal of the Chemical Society*, ii., 319. He immediately afterwards suggests that these compounds may be carbanilates or anthranilates, such as $C^4H^5,C^{14}H^6NO^4$ = Carbanilate or anthranilate of ethyl.

These salts are formed, experimentally, by the direct combination of the salt C^6H^5,CyO with the salts H,C^2H^5O, H,CH^3O, and $H,C^5H^{11}O$; precisely in the same manner as we produce a terbasic phosphate by combining a monobasic phosphate with similar salts on the model of water. I see no reason for doubting that these salts are terbasic cyanates, any more than I do for doubting whether there are such compounds as terbasic phosphates.

REACTIONS OF ANILOCYANIC ACID, or PHENYLA CYANATE, $C^6H^5;CyO$. The following reactions, (*a*) to (*f*), of the compound represented by No. 95] = $C^6H^5;CyO$, are given by Dr. Hofmann with a view to prove that the compound is an ACID (Anilo-cyanic acid) analogous to cyanic acid. *Quarterly Journal of the Chemical Society*, ii., 315. But they seem to prove only the presence of cyanate of phenyl, a salt in which H^1 of hydrated cyanic acid has been replaced by the radical phenyl C^6H^5.

a.)

$$\left.\begin{array}{rl} & C^6H^5,CNO \\ \text{Caustic potash} & \begin{cases} K,HO \\ K,HO \end{cases} \end{array}\right\} = \begin{cases} ZH,C^6H^5;H = \text{No. 1]} \\ KK,CO^3 \end{cases}$$

The cyanogen is decomposed; its carbon takes the potassium and oxygen, and forms carbonate of potash; its nitrogen takes the phenyl and hydrogen, and forms aniline or phenylac hydra, No. 1]. Two atoms of caustic potash are necessary to supply the quantity of K and O required to complete the carbonate, and of H to complete the aniline.

b).

$$\left.\begin{array}{rl} & C^6H^5,CNO \\ \text{Hydrochloric acid} & H,Cl \\ \text{Water . . .} & H,HO \end{array}\right\} = \begin{cases} ZH^3,C^6H^5;Cl = \text{No. 12]} \\ \qquad CO^2 \textit{ set free.} \end{cases}$$

In the presence of water and of the strong negative radical, Cl, first of all phenylam is formed, and then phenylam chlora, No. 12], commonly called Hydrochlorate of aniline; while the carbon carries off the oxygen in the state of carbonic acid.

$$c).\quad \left.\begin{array}{r} C^6H^5;\ CNO \\ \text{Sulphuric acid}\left\{\begin{array}{l} H,SOO \\ H,SOO \end{array}\right. \end{array}\right\} = \left\{\begin{array}{l} \left.\begin{array}{r} ZH,C^6H^5;\ SO \\ H\ ;\ SO^2 \end{array}\right\} \text{No. 28].} \\ \qquad\qquad CO^2 \end{array}\right.$$

In the presence of strong sulphuric acid, the cyanogen is decomposed, carbonic acid is set free, and the azote forms phenylac and then sulphanilic acid, No. 28] = $ZH,C^6H^5;\ SO + HSO^2$, or $H;\ ZH,C^6H^5;\ S^2O^3$.

$$d).\quad \left.\begin{array}{r} C^6H^5;\ CNO \\ C^6H^5;\ CNO \\ H\ ;\ HO \end{array}\right\} = \left\{\begin{array}{l} ZH^2,(C^6H^5)^2;\ CNO = \text{No. 90].} \\ \qquad\qquad\quad CO^2 \\ \end{array}\right.$$

In the presence of water, the cyanogen is decomposed, slowly at mean temperature, rapidly if heated; carbonic acid is given off, and the azote produces phenylem cyanate, No. 90], commonly called Carbanilide.

$$\begin{array}{ll} e). & \\ \text{No. 1]} & \end{array} \left.\begin{array}{r} C^6H^5;\ CNO \\ = ZH,C^6H^5;\ H\quad \end{array}\right\} = ZH^2,(C^6H^5)^2;\ CNO = \text{No. 90].}$$

When No. 95] is treated with aniline, No. 1], it produces carbanilide (phenylem cyanate), No. 90].

$$f).\quad \left.\begin{array}{l} C^6H^5;\ CNO \\ ZH^2;\ H \end{array}\right\} = ZH^2,C^6H^5;\ CNO = \text{No. 89].}$$

When No. 95] is treated with ammonia = ZH^2H, it produces carbamide-carbanilide (phenylam cyanate), No. 89].

These experiments do not prove that the compound C^6H^5,CyO is an acid; but what they do prove is, that nitrogen acts up to the character that I have assigned to it as a constructor of radicals. When it is in the presence of carbon, and without the materials necessary to constitute an amid or an ammon, it forms cyanogen; but so soon as materials are placed within its reach, wherewith it can make a salt of an amid or an ammon, it immediately forms such a salt, and leaves the carbon to its destiny, which appears to be that of occupying and removing the oxygen. What the precise result is, in each case, depends partly upon the nature of the materials that are employed, partly upon their relative quantities, and the manner of putting them together. In cases *a* and *c* the materials produce phenylac; in cases *b* and *f* they produce phenylam; in cases *d* and *e* they produce phenylem. In the presence of potassium the carbonic acid remains in the state of carbonate of potash. In the absence of positive radicals it flies off as gas.

On the subject of the transmigration of azote from amids and ammons into cyanogen, and thence back again into amids and ammons, the reader will find some additional particulars in the Article on "Nitriles," at page 217.

At a later period (January, 1856,) Dr. Hofmann ascribed to anilocyanic acid the formula $C^{14}H^{6}NO^{2}$. *Proceedings of the Royal Society*, viii. 13. But his analyses give $C^{14}H^{5}NO^{2}$ (November, 1849), *Quarterly Journal of the Chemical Society* (1850), ii. 314.

$$99]. \left\{ \begin{array}{r} C^{6}H^{5};\, CyO \\ (ZH,C^{6}H^{5};\, Cy)^{3} \end{array} \right\} = \text{Phenyla cyanate tris phenylac cyana.}$$

When melanoximide is distilled, the compounds produced are carbonic oxide gas, anilocyanic acid, and a residue having the following composition: $C^{64}H^{23}N^{7}O^{2}$ (Hofmann's numbers) $= C^{32}H^{23}N^{7}O^{1} =$ No. 99]. This decomposition may be accounted for as follows:

$$\begin{array}{lcl} \text{Used.} & & \overbrace{\hspace{9cm}}^{\text{Produced.}} \\ \text{3 atoms of No. 93.} & & \\ \left.\begin{array}{l} C^{6}H^{5},CyO \\ C^{6}H^{5},CyO \\ C^{6}H^{5},CyO \\ C^{6}H^{5},CyO + HCy \\ C^{6}H^{5},CyO + HCy \\ C^{6}H^{5},CyO + HCy \end{array}\right\} & = & \left\{\begin{array}{rl} \left.\begin{array}{r} C^{6}H^{5},CyO \\ C^{6}H^{5},CyO \end{array}\right\} & \begin{array}{c}\text{2 atoms} \\ \text{of 95].}\end{array} \\ \left.\begin{array}{l} C^{6}H^{5},CyO \\ ZH,C^{6}H^{5},Cy \\ ZH,C^{6}H^{5},Cy \\ ZH,C^{6}H^{5},Cy \end{array}\right\} & \begin{array}{c}\text{1 atom} \\ \text{of 99].}\end{array} \end{array}\right\} + \left\{\begin{array}{l} CO \\ CO \\ CO \end{array}\right\} \begin{array}{c}\text{Carbonic} \\ \text{oxide,} \\ \text{3 atoms.}\end{array} \end{array}$$

When water is present, additional reactions take place and complicate the phenomena. Thus:

$$\left.\begin{array}{r} C^{6}H^{5},CyO \\ C^{6}H^{5},CyO \\ H,\, HO \end{array}\right\} = \left\{\begin{array}{l} ZH^{2},(C^{6}H^{5})^{2};\, CyO = \text{No. 90].} \\ \qquad\qquad CO^{2} \textit{ set free.} \\ \end{array}\right.$$

Every atom of water decomposes two atoms of No. 95], $C^{6}H^{5},CyO$, and their materials produce one atom of carbanilide, No. 90], $ZH^{2},(C^{6}H^{5})^{2};\, CyO$, and one atom of carbonic acid, CO^{2}.

In reviewing Dr. Hofmann's account of the compounds of aniline, I have restricted my remarks to the individual substances selected for examples, and I have not entered upon the general speculation, whether the aniline bases are most consistent with Berzelius's idea that they all contain ammonia $= NH^{3}$, or with Liebig's, that they all contain amidogen $= NH^{2}$, &c. On these points Dr. Hofmann does not appear to have satisfied his own judgment, and his wavering arguments certainly settle nothing. In 1844 he quotes aniline with the formula $C^{12}H^{7}N$. In 1848 he is favourable to Berzelius's theory, and aniline is $NH^{3},(C^{12}H^{4})$. In 1850, farther researches make him incline to Liebig's view, and aniline is quoted as $\left.\begin{array}{c} H \\ H \\ C^{12}H^{5} \end{array}\right\} N$. In 1856, aniline becomes again what it was in

1844, $C^{12}H^7N$. In most cases these formulæ are given doubtingly, as if the arguments that are urged to support them had not appeared conclusive to their author.

As the theory of azotic radicals which I have advanced in this Essay is of wider application than any of the theories that have been advocated by Dr. Hofmann, and as the aniline salts, if my views are correct, must fall in with all other salts of azotic radicals, I leave it to the reader to form his own opinion respecting them, when I have placed before him the azotic theory in a more complete state.

The Platinum Bases.

It is impossible to examine the salts of platinum, and their distinguishing names and formulæ, without being driven to the conclusion that, on these matters, chemists are in a muddle.

Of course, the muddle is unnecessary, and might be removed. It does not depend upon difficulties inherent in the salts; for they are simple and regular, and their transmutations are characteristic and intelligible. The muddle is purely theoretical. It is the produce of the clumsy contrivances by which, from time to time, the salts of platinum have been EXPLAINED. If we could get rid of these explanations, we should get rid of the muddle, since the salts themselves are orderly; but, unhappily, chemists cherish two favourite dogmas, the retention of which perpetuates the muddle.

These are the dogmas:—

1. "*There is only one chemical equivalent of platinum.*"
2. "*The salts of platinum are composed of acids and bases.*"

REMARKS ON THE FIRST OF THESE DOGMAS.

M. Gerhardt, some years ago, showed chemists the propriety—nay, the *necessity*, of admitting the existence of two chemical equivalents of platinum, and he proved to them that this would diminish the muddle among its salts. Some ridiculed this notion, and some said it was "a very ingenious theory;" but I believe that no one, excepting Laurent, admitted its truth. They preferred the muddle.

Now I cannot understand why chemists persist in playing the part of Sphinx, and puzzling the world with philosophical riddles that require an Œdipus to solve them, when a plain, simple, and useful course is proposed for their adoption. I cannot perceive what principle of reason guides their judgment in this matter. They will *not* admit the existence of a "second equivalent" of platinum, and they *will* admit the existence of a score of "platinum bases" of the most monstrous and extravagant proportions and composition. And thus they encourage muddle.

I have collected for this section about a hundred of the principal salts of platinum. I have arranged them in four classes, and given them the formulæ which they ought to have in accordance with the radical theory. I have added to each salt its ordinary formulæ, its difficultly-pronounceable names, and such other information as is necessary to identify it, and to contrast the existing system with that which is now offered to replace it.

I admit the existence of two chemical equivalents of platinum. A heavy atom which has the atomic weight of 99, and a light atom of half that weight. The first is to be called the *platous* atom, and the second the *platic* atom.

These two chemical atoms produce two distinct classes of salts, being those which are commonly called salts of the *protoxide*, and salts of the *peroxide* of platinum. An inspection of the formulæ which I have given in the following Table, Nos. 1] to 33] will convince any one whose judgment is unperverted by the "idols of the schools," that the separation of the salts Nos. 1] to 15] from those of Nos. 16] to 33], on the pretence that the former are salts of the protoxide, and the latter salts of the peroxide of platinum, is an unqualified absurdity. Oxygen is powerless in the matter. The real difference in the two classes of salts is obviously in the PLATINUM and ONLY in the *platinum*; and the true question for investigation is, What is the NATURE of *that difference?*

The nature of that difference is, that the platous salts contain the heavy atom of platinum, and the platic salts contain the light atom; all other elements of the salts remaining the same.

The difference that exists between the platous and platic salts, exists also between the salts of platousam and platicam. By platousam, I mean an ammonium which contains one platous atom; by platicam, an ammonium that contains one platic atom. These ammoniums act as positive radicals, and each of them produces a variety of salts. These salts are given in the following Table, where Nos. 34] to 68] are salts of platousam, and Nos. 70] to 100] are salts of platicam. Throughout these extended sets of salts, the characteristic of the first set is the presence of the platous atom, and of the last set the presence of the platic atom.

It is completely in the power of the chemist to produce at pleasure either the platous or the platic atom. The certainty of the very existence of platinum is not greater than the certainty that the chemist has it in his power to produce at will either platous salts or platic salts, either salts of platousam or salts of platicam. And to do this, he must produce either the platous or the platic atom. The following are the facts which guide him:

1. When platinum is acted on by a negative radical, in the presence of an excess of positive radicals, the platous atom is produced.

2. When platinum is acted on by a negative radical, in the presence of an excess of negative radicals, the platic atom is produced.

The salts that are described in the following Tables, are produced by processes that are in perfect accordance with these facts. The salts of platousam are all produced by the action of positive radicals in excess; and it is only in this class that we meet with those combinations of neutral salts with ammonia, which in Gerhardt's language are called salts of diplatosamine; while on the other hand, we perceive in the salts of platicam a total absence of an excess of ammonia, and in their formation the constant recurrence of the splitting up of platous into platic atoms by the energetic action of negative radicals presented to the platinum in excess. It is scarcely possible to conceive the existence of evidence of a circumstantial character more conclusive than is presented by the salts that are described in these Tables in support of the principle which I am advocating, that platinum has two different chemical atoms, that either of them is producible, or convertible into the other, at the will of the chemist, and that to the diversity of their reactions all the salts of platinum owe their peculiar characteristics.

What I have stated respecting the mutability of the chemical atom of platinum is strictly in accordance with what I have stated in another section—see page 34—respecting the mutability of the chemical atom of iron. I have shown there, that under the action of an excess of positive radicals, the ferrous atom is formed, and that, under the pressure of an excess of negative radicals, the ferric atom is produced. This kind of reaction is no doubt common, in a greater or lesser degree, to all elements which are endowed with the property of producing two different radicals. The natural tendency of matter to come to an equilibrium occasions these peculiar chemical elements to form their larger or their smaller radical according as the circumstances in which they are placed demand the one or the other. The power to control the elements, and make them produce the basylous or basylic atoms as he requires them, depends entirely on the chemist's ability to arrange the circumstances in which the elements are to be made to act. This was the secret of the "wonderful lamp." When Aladdin rubbed the lamp, the genius appeared to do his bidding. When the chemist desires to produce a particular chemical atom, he arranges the proper circumstances, and nature does his bidding.

By admitting the mutability of elementary chemical radicals to be the result of a natural law which is in continual operation, we are enabled to account, in a simple and easy manner, for a great variety of complex chemical phenomena, which are otherwise perfectly unaccountable. Under these circumstances, it is extraordinary that chemists persist in rejecting evidence which is clear and abundant, for no better reason than that Dalton, fifty years ago, defined a chemical equivalent to be *one indivisible atom.* Why are we to be bound by a definition which never rested on evidence stronger than a surmise, when that definition is contradicted by the facts accumulated by fifty years of analytical research?

We have to this day no evidence of the existence of indivisible atoms. We have abundant evidence of the power possessed by more than twenty elements to produce two different chemical atoms, each of them having the power of a radical, and each being able to produce a series of salts differing in quality from the salts produced by the other radical. But fashions in chemistry are not always regulated by experimental evidence. Dalton's theory is become an "idol of the schools," and sacrifices are made to it.

REMARKS ON THE SECOND DOGMA.

"*The salts of platinum are composed of acids and bases.*"

The reader is requested to look over the formulæ that accompany the synonymes in the following Table of 99 salts of platinum. The doctrine that every salt is composed of an *acid* and a *base*, has, in this case, led its votaries to the adoption of some extraordinary absurdities. According to that doctrine, a normal nitrate is composed thus: MO,NO^5, where MO is the base, and NO^5 is the acid. But here is an exquisite platinum-nitrate, No. 85]: $4NH^3,Pt^2ClO^5,2NO^5$. That doctrine professes to discountenance binitrates, but here it admits the existence of a binitrate. That doctrine declares it to be a fundamental law, that in every salt the number of atoms of anhydrous acid must be equal to the number of atoms of oxygen in the base. Yet here we have five atoms of oxygen in the base, and only two atoms of anhydrous acid to bring that base into equilibrium. Then, what a base it is! What a radical it contains! *Four* atoms of nitrogen, *twelve* atoms of hydrogen, *two* atoms of platinum, and *one* atom of chlorine are all conglomerated into one basic clump—that clump is oxidised into a base by *five* atoms of oxygen, and that one base is then combined directly with *two* atoms of anhydrous nitric acid to form a nitrate. This is gravely recorded as matter for belief by philosophers who are too squeamish to admit the possibility that platinum can produce two different chemical atoms. In order to escape this last difficulty, and to do reverence to the Daltonian "idol," they take a salt which, as formula 85] shows, contains four complete ammoniums and four acid radicals, and which therefore is a quadruple salt; and, after setting aside as the "acid," the clump "$2NO^5$," they cram all the other ingredients into the "base," thus making a salt by a series of processes every one of which is in violation of the laws that constitute the doctrine which they pretend to support. I ask any independent thinker whether this is not "muddle?" whether it is not a striking example of the ability to swallow a camel and strain at a gnat?

Here is another admirable example of theoretical architecture:

$$\left\{\begin{matrix}\left.\begin{matrix}\mathrm{H^3}\\\mathrm{PtCl}\end{matrix}\right\}\mathrm{N}\\\mathrm{H^3}\end{matrix}\right\}\mathrm{NCl}.$$

This salt, as I regard it, is formed on the model of sal-ammoniac; a chloride of an ammonium, in which one atom of hydrogen has been replaced by one platic atom, and which requires on the radical theory the simple formula which I have given to it in No. 70], viz., ZH^3Ptc; Cl. But this radical formula is very simple, and it contains the heterodox platic atom; it is therefore doubly objectionable to the established chemical authorities. The orthodox view of the salt is this: " It is the chloride of an ammonium. This ammonium has one of its atoms of hydrogen replaced by another ammonium. This other ammonium has one of its atoms of hydrogen replaced by the protochloride of platinum, and thus we obtain the compound:

$$= \left\{ \begin{matrix} \left.\begin{matrix} H^3 \\ PtCl \end{matrix}\right\} N \\ H^3 \end{matrix} \right\} NCl."$$

But some of our orthodox chemists dissent from this view of the salt. They do not admit the truth of this theory of involved ammoniums, where the smaller is made to include the greater. Instead of grouping the elements in that form, they put them side by side in regimental order, thus:—$Pt^2Cl^2O^2H^{12}N^4 + O^2$, and they call this regiment a BASE—" Raewsky's base." The particular nature of this " base" is not made by any means clear to us. Whether the elements are combined in any special grouping, or whether they stand side by side like posts in a pallisade, a series of chemical nullities waiting for the "acid" that is to rail them into united action, we are not informed.

By similar processes, chemists manufacture a host of " platinum bases," of which I will try to quote a few examples. I hope I shall quote them satisfactorily, but it is so difficult to know when you have the whole of a " platinum base," that in extracting it from its salts, you are very liable to take away a few atoms too many, or leave behind a few that ought to be taken. In the estimation of many orthodox chemists, however, if we may judge from the following formulæ, a few atoms more or less in a platinum base seems to be considered a matter of little importance:

1. Gros's base . . . $PtClH^6N^2 + O$ or $PtClH^2N,NH^4O$.
2. Reiset's first base . $PtH^6N^2 + O$ or PtH^2N,NH^4O.
3. Reiset's second base . $PtH^3N + O$ or $\left.\begin{matrix} Pt \\ H^3 \end{matrix}\right\} NO$.
4. Raewsky's first base $Pt^2Cl\,O^3H^{12}N^4 + O^2$.
5. Raewsky's second base $Pt^2Cl^2O^2H^{12}N^4 + O^2$.

Grimm's Notation. Hofmann's Notation.

6. Gerhardt's Platosamine . . $NH^2Pt = \left\{\begin{matrix} H^3 \\ Pt \end{matrix}\right\} NO,HO$.

Grimm's Notation. Hofmann's Notation.

7. Gerhardt's Diplatosamine. . $N^2H^5Pt = \left\{\begin{matrix} PtH^6N^2O,HO. \\ \left\{\begin{matrix} H^2 \\ H^4N \\ Pt \end{matrix}\right\} NO,HO. \end{matrix}\right.$

8. Gerhardt's Platinamine . . $NHpt^2 = \left\{\begin{matrix} H^2 \\ pt^2 \end{matrix}\right\} NO,HO.$

9. Gerhardt's Diplatinamine . $N^2H^4pt^2 = \left\{\begin{matrix} H \\ pt^2 \\ H^4N \end{matrix}\right\} NO,HO.$

The next six are given by Grimm on the authority of Kolbe:—

10. Platammonium $= \left\{\begin{matrix} Pt \\ H^3 \end{matrix}\right\} N.$

11. Ammon-Platammonium $= \left\{\begin{matrix} H^4N \\ Pt \\ H^2 \end{matrix}\right\} N.$

12. Oxyplatammonium $= \left\{\begin{matrix} PtO \\ H^3 \end{matrix}\right\} N.$

13. Ammon-Oxyplatammonium $= \left\{\begin{matrix} H^4N \\ PtO \\ H^2 \end{matrix}\right\} N.$

14. Chlorplatammonium $= \left\{\begin{matrix} PtCl \\ H^3 \end{matrix}\right\} N.$

15. Ammon-Chlorplatammonium $= \left\{\begin{matrix} H^4N \\ PtCl \\ H^2 \end{matrix}\right\} N.$

All these bases, and as many more as can be produced by numerous variations in the methods of writing the formulæ, the student of chemistry is led to believe to be necessary for the explanation of the salts of platinum.

In the Renowned History of the Seven Champions of Christendom it is recorded that the Necromancers of the middle ages—no doubt, the orthodox chemists of that period—were in the practice of defending unsafe positions by Fortifications and Giants and Dragons of hideous aspect and ugly names, *all constructed of* MIST. It seems to me that the Platinum Bases have been made of the same material by descendants of those Necromancers in order to protect the rickety theory of acids and bases which they delight to honour.

These "bases" are, actually, mere mist—castles built in the air, with no solid foundations. If you touch them with the inflexible rod of the Radical Theory, it smashes them, and they vanish. The true platinum radicals—which bear examination, and do not fly into mist, if you ask them a question or two, are the following: the platous atom = Pt, the platic atom = Ptc, platousam = ZH^3Pt, and platicam = ZH^3Ptc. With these only, I proceed to formulate the entire series of the salts of this malicious metal, which, acting the part of the chemical "Puck," has hitherto led philosophers a pretty dance into all sorts of quagmires.

It is high time for orthodox chemists to unmuzzle their wisdom, and begin to inquire whether "acids" and "bases" have not been "idolized" a little too long; and whether it is safe for them to continue to treat with supercilious contempt all proposals to examine into the constitution of salts, because the proposers decline to worship with them the misty phantoms which were the progeny of the half-knowledge, half-ignorance of a preceding generation.

Salts of Platinum.

DEFINITIONS OF THE PLATINUM RADICALS.

PLATOUS signifies the heavy chemical atom of platinum. Atomic weight, 99. Symbol, Pt.

PLATIC signifies the light chemical atom of platinum. Atomic weight 49·5. Symbol, Ptc.

PLATOUSAM signifies an ammonium in which one atom of hydrogen has been replaced by one platous atom. Symbol, ZH^3Pt.

PLATICAM is an ammonium in which one atom of hydrogen has been replaced by one platic atom. Symbol, ZH^3Ptc.

These four Radicals produce four distinct Classes of Salts.

Class I. Platous Salts.

PtO (like CO)	1.	Pt,PtO	Platous platousate.
PtS	2.	PtS	Platous sulpha.
$PtCl_2$	3.	$PtCl$	Platous chlora.
	4.	$PtCl + ZH^4Cl$	Platous chlora cum ammona chlora.
	5.	$Pt; ZH^4; S^2O^3$	Platous ammona sulphenite.
	6.	PtI	Platous ioda.
	7.	$PtCy$	Platous cyana.
	8.	H,Pt,Cy^2	Hydra platous cyanen.
	9.	ZH^4,Pt,Cy^2	Ammona platous cyanen.
	10.	K,Pt,Cy^2	Potassa platous cyanen.
	11.	$(K,Pt,Cy^2)^5 + KCy$	Pentakis potassa platous cyanen cum potassa cyana.

12. $(ZH^4,Pt,Cy^2)^5 + ZH^4Cy$	Pentakis ammona platous cyanen cum ammona cyana.
13. Pt,Cy,S^2	Platous cyana sulphene.
14. K,Pt,Cy^2,S^4	Potassa platous cyanen sulphone.
15. $Ag,Pt,Cy,^2S^4$	Argenta platous cyanen sulphone.

USUAL NAMES AND FORMULÆ OF THE PLATOUS SALTS.

In these Formulæ, $O = 8$. $Pt = 99$.

1, Protoxide of platinum; platinous oxide = PtO. 2, Protosulphide of platinum; platinous sulphide = PtS. 3, Protochloride of platinum; platinous chloride; chloroplatinous acid = $PtCl$. 4, Chloroplatinate of ammonium = $NH^4Cl,PtCl$, *Peyrone.* (This is the model of three series of salts. In one of them, the chloroplatinites, ZH^4 is replaced by K or some other metal. In the other two series, the two atoms of Cl are replaced by Br^2 or I^2, giving rise to the bromoplatinites and iodoplatinites.) 5, Sulphite of platinous oxide and ammonia = $NH^4O,SO^2 + PtO,SO^2$. 6, Protoiodide of platinum; platinous iodide; iodoplatinous acid = PtI. 7, Protocyanide of platinum; platinous cyanide = $PtCy$. 8, Hydroplatinocyanic acid = $HCy,PtCy$. 9, Platinocyanide of ammonium = $NH^4Cy,PtCy$. 10, Platinocyanide of potassium = $KCy,PtCy$. Numbers 9 and 10 are models of a large class of salts, which differ only in having, in the place of ZH^4 and K, one of these radicals, Ba, Ca, Mg, Cuc, Hgc, Ag. 11, Platino-platinidcyanide of potassium = $K^6Pt^5Cy^{11}$ = $KCy,5KPtCy^2$. 12, Platino-platinidcyanide of ammonium = $(NH^4)^6Pt^5Cy^{11} = NH^4Cy,5(NH^4PtCy^2)$. There are many other salts on the model of Nos. 11 and 12, in which ZH^4 and K give place to Na, Ca, Mg, Pb, Fe, &c. 13, Sulphocyanide of platinum = $PtCyS^2$. 14, Platino-bisulphocyanide of potassium = $KPtC^4N^2S^4 = KPt\,2(CyS^2)$. 15, Platino-bisulphocyanide of silver = $AgPt\,2(CyS^2)$.

Nos. 1 to 12 are given on the authority of Gmelin's Handbook of Chemistry. Nos. 13 to 15 are on the authority of Buckton.

$NaO, 3PtO_2$ or $\left.\begin{matrix}Na_2\\Pt_3\end{matrix}\right\}\Theta_7$ shows Pt to be quadribasic. Hence my formulae.

C. S. P.

Class II.—Platic Salts.

PtO_2	16. $Ptc,PtcO$	Platic platicate.
$PtH_4.O_4$	17. Ptc,HO	Platic hydrate.
	18. $PtcS$	Platic sulpha.
$PtCl_4$	19. $PtcCl$	Platic chlora.
$K_2Pt.Cl_6$	20. $KCl + 2PtcCl$.	Potassa chlora bis platic chlora.
	21. $NaCl + 2PtcCl$.	Natra chlora bis platic chlora.
	22. $ZH^4Cl + 2PtcCl$.	Ammona chlora bis platic chlora.
	23. $PtcI$	Platic ioda.
$NH_4I.PtI_4$	24. $ZH^4I + 4PtcI$.	Ammona ioda tetrakis platic ioda.
	25. $H,Ptc^2; I^3$ . . .	Hydra platenic iodine.
$PtI_3.I_3Pt$	26. $Pt,Ptc^2; I^3$ . . .	Platous platenic iodine.
	27. $PtcSO^2$	Platic sulphete.
	28. $KCl + 2PtcCy$.	Potassa chlora bis platic cyana.
	29. $ZH^4Cl + 2PtcCy$.	Ammona chlora bis platic cyana.
	30. ZH^4, Ptc^2,Cy^3 . .	Ammona platenic cyanine.
	31. K,Ptc^2,Cy^3 . . .	Potassa platenic cyanine.
	32. ZH^4,Ptc^2,Cy^3,S^6 . .	Ammona platenic cyanine sulphade.
	33. K,Ptc^2,Cy^3,S^6 . .	Potassa platenic cyanine sulphade.

USUAL NAMES AND FORMULÆ OF THE PLATIC SALTS.

In these formulæ $O = 8$, $Pt = 99$.

16, Platinic oxide; bioxide of platinum = PtO^2. 17, Hydrate of platinic oxide; platinic hydrate = $PtO^2,2HO$. 18, Bisulphide of platinum; platinic sulphide = PtS^2. 19, Bichloride of platinum; platinic chloride; chloroplatinic acid = $PtCl^2$. 20, Chloroplatinate of potassium = $KCl,PtCl^2$. 21, Chloroplatinate of sodium = $NaCl,PtCl^2$. 22, Chloroplatinate of ammonium = $NH^4Cl,PtCl^2$. There are other salts on the model of Nos. 20 to 22. The salts that are called chloroplatinites are formed on the model of No. 4. 23, Biniodide of platinum; platinic iodide; iodoplatinic acid = PtI^2. 24, Iodoplatinate of ammonium = $NH^4I,2PtI^2$. (Instead of the name and formula which I have given in the Table, we could also write ZH^4,Ptc^4,I^5 = Ammona platonic iodune). 25, Hydriodate of platinic iodide = PtI^2,HI. 26, Sesqui-iodide of platinum = Pt^2I^3. (This seems to be a salt precisely corresponding to No. 25. There are equivalent salts with K,Na, &c., instead of Pt; and a corresponding series with Br instead of I). 27, Sulphate of platinic oxide; platinic sulphate = $PtO^2,2SO^3$. Two atoms of sulphuric acid are required, because two atoms of oxygen are assumed to be present in the base in combination with only one atom of metal; so that eight atoms of oxygen are demanded by the current theory, while two atoms

$$\left.\begin{matrix}Pt\\ 2\,SO\end{matrix}\right\}O_4$$

suffice on the radical theory. 28, Bicyanide of platinum with chloride of potassium = $KCl,PtCy^2$. 29, Bicyanide of platinum with chloride of ammonium = $NH^4Cl,PtCy^2$. 30, Platinidcyanide of ammonium = $NH^4Cy, PtCy^2$. 31, Platinidcyanide of potassium = $KCy, PtCy^2$. 32, Platino-tersulphocyanide of ammonium = $NH^4,Pt\,3CyS^2$. 33, Platino-tersulphocyanide of potassium = $KPtC^6N^3S^6 = KPt\,3CyS^2$. Nos. 32 and 33 are models of a series of salts in which K and ZH^4 are replaced by Fe, Hg, Ag, Pb, and H. See Buckton, *Quarterly Journal of the Chemical Society*, vii. 22. The names and formulæ from No. 16 to 31 are taken from *Gmelin's Handbook of Chemistry*.

Class III.—Salts of Platousam = ZH^3Pt.

34.	$ZH^3Pt; Cl$		Platousam chlora.
35.	$ZH^3Pt; Cl + ZH^2,H$		Platousam chlora cum amida hydra.
36.	$ZH^3Pt; Br$		Platousam broma.
37.	$ZH^3Pt; Br + ZH^2,H$		Platousam broma cum amida hydra.
38.	$ZH^3Pt; I$		Platousam ioda.
39.	$ZH^3Pt; I + ZH^2,H$		Platousam ioda cum amida hydra.
40.	$ZH^3Pt; HO$		Platousam hydrate.
41.	$ZH^3Pt; ZH^3PtO$		Platousam platousamate.
42.	$ZH^4; ZH^3PtO$		Ammona platousamate.
43.	$ZH^3Pt; SO^2$		Platousam sulphete.
44.	$ZH^3Pt; SO^2 + ZH^2,H$		Platousam sulphete cum amida hydra.
45.	$ZH^3Pt; NO^3$		Platousam nitrite.
46.	$ZH^3Pt; NO^3 + ZH^2,H$		Platousam nitrite cum amida hydra.
47.	$ZH^4; ZH^3Pt; CO^3$		Ammona platousam carbite.
48.	$ZH^4; ZH^3Pt; CO^3$ $ZH^4; ZH^3PtO$		Ammona platousam carbite cum ammona platousamate.
49.	$ZH^3Pt; Cy$		Platousam cyana.
50.	$ZH^3Pt,Cy + AgCy$	=	Platousam cyana cum argenta cyana.
51.	$ZH^3Pt,Cy + Zn\,Cy$	=	Platousam cyana cum zinca cyana.
52.	$ZH^3Pt,Cy + Co\,Cy$	=	Platousam cyana cum cobaltous cyana.
53.	$ZH^3Pt,Cy + Ni\,Cy$	=	Platousam cyana cum niccolous cyana.
54.	$ZH^3Pt; Cy; S^2$		Platousam cyana sulphene.
55.	$ZH^4; ZH^3Pt; S^2O^3$		Ammona platousam sulphenite.
56.	$ZH^4; ZH^3Pt; S^2O^3$ $ZH^3Pt; ZH^3Pt; S^2O^3$		Ammona platousamine bisulphenite.

57.	$\left\{\begin{matrix} ZH^4;\ ZH^3Pt;\ S^2O^3\ .\ \ .\ \ . \\ ZH^4;\ ZH^4\ \ ;\ S^2O^3\ .\ \ .\ \ . \end{matrix}\right\}$	Ammonine platousam bisulphenite.
58.	$\left\{\begin{matrix} (ZH^4;\ ZH^3Pt;\ S^2O^3)^2 \\ ZH^4;\ Cl \end{matrix}\right\} + \frac{1}{2}\,Aq.$	Bis ammona platousam sulphenite cum ammona chlora demi-aquate.
59.	$\left\{\begin{matrix} ZH^4;\ ZH^3Pt;\ S^2O^3 \\ ZH^3Pt;\ Cl \end{matrix}\right\} + Aq.$	Ammona platousam sulphenite cum platousam chlora aquate.
60.	$ZH^3Pt;\ Cl + ZH^3Cuc\ ;\ Cl$	Platousam chlora cum cupricam chlora.
61.	$ZH^3Pt;\ Cl + ZH^3Hgc;\ Cl$	Platousam chlora cum mericam chlora.
62.	$ZH^3Pt;\ Cl + ZH^3Pb\ ;\ Cl$	Platousam chlora cum plumbam chlora.
63.	$ZH^3Pt;\ Cl + ZH^3Zn\ ;\ Cl$	Platousam chlora cum zincam chlora.
64.	$ZH(C\,H^3)^2Pt;\ Cl + ZH^2,H$	Platous - methylem chlora cum amida hydra.
65.	$ZH(C^2H^5)^2Pt;\ Cl + ZH^2,H$	Platous-ethylem chlora cum amida hydra.
66.	$ZH(C^6H^5)^2Pt;\ Cl + ZH^2,H$	Platous - phenylem chlora cum amida hydra.
67.	$ZH^2,C^6H^5,\ Pt;\ Cl\ \ .\ \ .\ \ .$	Platous-phenylam chlora.
68.	$ZH^3,C^6H^5;\ Cl + PtCl\ \ =$	Phenylam chlora cum platous chlora.

USUAL NAMES AND FORMULÆ OF THE SALTS OF PLATOUSAM.

34]. $ZH^3Pt;\ Cl$ = Platousam chlora.

This formula represents a compound which contains the following proportions of the respective elements:

Nitrogen . . . . 1 atom = 14
Hydrogen . . . 3 atoms = 3
Platinum . . . 1 atom = 99
Chlorine . . . . 1 atom = 35·5

There are several ways of preparing a compound of this composition, and the compounds thus prepared, though similar in their ultimate composition, have different properties, and give rise to the notion that they differ in their *proximate* constitution. Three varieties may be specially noticed:

a). *The Green Salt of Magnus* is prepared thus: A solution of protochloride of platinum (3] Platous chlora) in hydrochloric acid is supersaturated with ammonia. The platous atom undergoes no change, and the quantity of chlorine remains the same, but they combine with ammonia, and the question is, in what manner are the four atoms, $Z + H^3$, connected with the two atoms $Pt + Cl$. In formula 34] it is assumed that $Z + H^3 + Pt$ have produced the vice-ammon *platousam*, and that this is combined directly with the chlorine. But the facts admit of various other explanations. Thus, we may assume that the platous chlora = $PtCl$ combines directly with the ammonia—salt to salt—and produces the double salt = $PtCl + ZH^2,H$; and, since many salts of platousam possess this property of combining with ZH^2,H (see Nos. 35, 37, 39, 44, 46), it is not unreasonable to suppose that the same power of combination may also exist in the platous salts.

Another explanation is, that the combination may be of the same nature as the hydrochlorate of ammonia (see page 197); and, in that view, may require the formula $ZH,Pt; H + HCl$. In this formula ZH,Pt represents a vice-amidogen; the formula $ZH,Pt; H$ the corresponding ammonia, and the formula HCl the hydrochloric acid requisite to constitute a hydrochlorate of this peculiar ammonia.

One of the methods of preparing the compound under consideration consists in adding platous chlora, = $PtCl$, to the salt represented by formula 35] = $ZH^3Pt; Cl + ZH^2H$, which may thus produce a compound of the following formula, $(ZH^3Pt; Cl + ZH^2H) + PtCl$.

Finally, we can imagine the existence in this compound of the radical *platousem* = ZH^2Pt^2, which would then require the following formula: $ZH^2Pt^2; Cl + ZH^4Cl$.

We have thus five formulæ, all of which express the same quantities of the same elements, but differ greatly in their proximate arrangement, and every one of which has some claim to be considered the right formula:

1). $ZH^3Pt; Cl.$
2). $PtCl \quad + ZH^2H.$
3). $ZH,Pt; H + HCl.$
4). $(ZH^3,Pt; Cl + ZH^2H) + PtCl.$
5). $\left\{\begin{matrix} ZH^2Pt^2; Cl \\ ZH^4 \quad ; Cl. \end{matrix}\right\}$

It is not unlikely that some of the duplicate salts of this series may require formulæ similar to No. 5), containing platousem instead of platousam; but in the present state of our knowledge of these compounds, while it is easy to construct such formulæ, it is impossible to ascribe them with any certainty to the proper compounds.

b). *The Yellow Salt.*—Preparation 1). The compound No. 35], = $ZH^3Pt; Cl + ZH^2H$, is heated as long as it gives off ammonia. 2). The green salt is dissolved in a boiling solution of sulphate of ammonia. When the solution cools, the yellow salt is deposited. There are several other methods, but none which gives any precise information respecting the proximate constitution of the salt. When the yellow salt is dissolved in aqueous ammonia, the salt No. 35] is reconstituted. The yellow salt is sometimes called the hydrochlorate of Reiset's second base.

c.) *The Red Salt.*—Carbonate of ammonia is added, drop by drop, to a boiling solution of neutral protochloride of platinum, No. 3]: the red salt crystallises when the solution cools. If carbonate of ammonia is added at once in great excess to a cold solution of protochloride of platinum, the *yellow* salt is produced.

There appear to be several other compounds of this same percentage composition (see Gmelin's *Handbook of Chemistry*, vi. 300), but neither the methods of preparing them, or of converting them into other compounds, nor their properties or reactions, enable us to allot to them with certainty any one of the above formulæ in preference to the others. The prevailing opinion of chemists is, that the green salt contains twice as many atoms as the other salts, but this opinion does not rest on any strong foundation.

Synonymes.—Chloride of diplatosammonium, *Buckton.* Ammonio-protochloride of platinum, with one atom of ammonia = $NH^3,PtCl$, *Gmelin.* Hydrochlorate of platosamine = ClH,NH^2Pt, *Gerhardt*; but according to him the green salt is chloroplatinite of diplatosamine = $PtCl^2H,N^2H^5Pt$. Platammoniumchlorür = $\left\{\begin{matrix}P\\H^3\end{matrix}\right. NCl$, *Grimm* (the yellow salt). Ammon-Platammoniumchlorür-Platinchlorür = $\left\{\begin{matrix}H^4N\\Pt\\Cl^2\end{matrix}\right\} NCl + PtCl$, *Grimm* (the green salt).[1] Miller calls the yellow salt Hydrochlorate of platosamine (Reiset's second base) = PtH^3N,Cl; while he calls the green salt Magnus's green salt (Reiset's first base) = $PtH^6N^2Cl + PtCl$. This last formula agrees with No. 4) in the above list of *possible* formulæ. An objection to this particular formula is, that it is difficult to understand how it happens that ($ZH^3Pt; Cl + ZH^2H$) + $PtCl$ does not instantly become $ZH^3Pt; Cl + ZH^3Pt; Cl$, a compound which requires formula 1).

35]. $ZH^3Pt; Cl + ZH^2H$. Platousam chlora cum amida hydra.

Under the head of "Ammoniated Salts," at page 198, I have explained the nature of the compounds that are formed by the combination of ammonia with neutral salts. It is of importance to bear in mind that these compounds are double salts, because it clears away one of the difficulties in the theory of the platinum bases. Gmelin's name and formula for this salt are Ammonio-protochloride of platinum, with two atoms of ammonia = $2NH^3,PtCl$. He gives the following account of its preparation. "Protochloride of platinum is immersed in aqueous ammonia, and boiled with it, the liquid being frequently renewed till the green compound of Magnus, which is formed at first with evolution of heat, is dissolved, after which the solution is evaporated to the crystallizing point. The green salt of Magnus may likewise be treated in a similar manner. (*Reiset*)." These reactions seem pretty clear:

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[1] Grimm's names and formulæ are quoted from Liebig's Handwörterbuch der Chemie, Band vi. To save room, I shall here quote his 3-line formulæ in one line, thus: $(H^4N,Pt,Cl^2)NCl + PtCl$. The reader will understand, that the quantities that are placed within the parenthesis, and pointed off by commas, must be placed in a column to represent Grimm's formula.

First reaction: $PtCl + ZH^4,HO = ZH^3Pt,Cl + HHO.$
Second reaction: $ZH^3Pt,Cl + ZH^4,HO = ZH^3Pt,Cl + ZH^2H + HHO.$

Gerhardt's name for No. 35] is Hydrochlorate of diplatosamine = HCl,N^2H^5Pt. Grimm calls it Ammon-Platammoniumchlorür = $(H^4N,Pt,H^2)NCl$. Buckton's name is Chloride of diplatosammonium = PtH^6N^2Cl. Miller calls it Hydrochlorate of diplatosamine (or Reiset's first base) = PtH^6N^2,Cl.

When this salt is heated in a tube, it gives off ZH^2H, and produces the *yellow* variety of No. 34]. When its solution is mixed with solution of No. 3], it produces the *green* variety of No. 34]. Buckton has described a remarkable reaction with this salt. He mixed a solution of it with sesquichloride of iron, expecting to obtain a double chloride similar to those described at Nos. 60] to 63]. In that expectation he failed; but he procured a precipitate which, on analysis, proved to be Platicam chlora, No. 70] = ZH^3Ptc,Cl. After precipitation of the iron solution by an excess of the platinum salt, he found the solution to contain no sesquichloride, but only protochloride of iron, the disengaged equivalent of chlorine, having, according to him, united itself to the platinum chloride, as represented in the following equation:

$$PtH^6N^2Cl + Fe^2Cl^3 = PtClH^6N^2,Cl + 2(FeCl).$$

According to my notation, this reaction is explained as follows:

$$ZH^3Pt\,;\,Cl + ZH^2H + Fec^2Cl^3 = ZH^3Ptc\,;\,Cl + ZH^3Ptc\,;\,Cl + Fe^2Cl^2.$$

That is to say, the three ferric atoms in the presence of a basic compound become two ferrous atoms, and abandon one atom of chlorine. This free chlorine converts the one platous atom into two platic atoms, and sufficient hydrogen and nitrogen to form two vice-ammons being present, the products are two atoms of platicam chlora, and two atoms of ferrous chlora.

36]. $ZH^3Pt\,;\,Br$ = Platousam broma
37]. $ZH^3Pt\,;\,Br + ZH^2H$ = Platousam broma cum amida hydra.
38]. $ZH^3Pt\,;\,I$ = Platousam ioda.
39]. $ZH^3Pt\,;\,I + ZH^2H$ = Platousam ioda cum amida hydra.

These four salts are evidently the corresponding salts to 34] and 35], the only difference being in the replacement of the negative radical Cl by Br or I. It is consequently needless to enter into details respecting them.

40]. $ZH^3Pt; HO$ = Platousam hydrate.

Dr. Hofmann, speaking of the Platosamine bases, says—"The free base, which Brodie has recently produced, has the composition $\left.\begin{matrix}H^3\\ Pt\end{matrix}\right\} NO,HO$, and is consequently a true Platosammoniumoxydhydrate." *Supplemente zum Handwörterbuche der Chemie*, p. 473. I can find no account of this substance. Compare No. 40] with No. 41]. Which of these salts did Brodie discover?

41]. $ZH^3Pt; ZH^3PtO$ = Platousam platousamate.

This compound is produced when No. 42] is exposed to heat.

$$\left.\begin{matrix}ZH^4; ZH^3PtO\\ ZH^4; ZH^3PtO\end{matrix}\right\} = \left\{\begin{matrix}ZH^3Pt; ZH^3PtO\\ ZH^2H + ZH^2H + HHO.\end{matrix}\right.$$

This is the hydrate of Gerhardt's Platosamine, and Reiset's second base. It forms a grey porous mass, insoluble in water and in ammonia. Dr. Miller's formula for Platosamine is PtH^3N,O.

42]. $ZH^4; ZH^3PtO$ = Ammona platousamate.

This compound is obtained by precipitating the solution of the sulphate No. 44] with baryta-water:

$$ZH^3Pt; SO^2 + ZH^2H + BaHO = ZH^4; ZH^3PtO + BaSO^2,$$

or by acting upon the salt No. 35] by oxide of silver (that is to say, newly-precipitated, or in the state of hydrate):—

$$ZH^3Pt; Cl + ZH^2H + AgHO = ZH^4; ZH^3PtO + AgCl,$$

Gmelin gives it the formula $2NH^3,PtO,HO$, and calls it Ammonio-protoxide of platinum, or Platinite of ammonia, with two atoms of ammonia and one atom of water. According to Berzelius, the formula is $NH^3PtO + NH^4O$. If O is taken = 16, this formula agrees with mine. Grimm calls it Ammon-platammoniumoxydhydrate = (H^4N,Pt,H^2) NO.HO. Gerhardt's formula is $N^2H^5Pt + 2HO$. The first division of this formula = N^2H^5Pt, represents an imaginary base which Gerhardt called Biplatosamine or Diplatosamine. Dr. Miller's formula for Diplatosamine is $PtH^6N^2,O + HO$. A name by which this compound is frequently distinguished is "Reiset's first base." Reiset's "second" base is the radical of No. 41]. Dr. Hofmann gives the following account of the present compound. "The constitution of the base is not so simple as that of the Platosammoniumoxydhydrate (No. 40). It contains the elements of that compound + 1 equiv. ammonia

$$PtH^6N^2O,HO = \left.\begin{matrix}H^3\\ Pt\end{matrix}\right\} NO.HO + H^3N.$$

We have at this moment nothing to guide us in forming an opinion of the manner in which this equivalent of ammonia is combined with the Platosammoniumoxydhydrate. If we adopt Graham's idea, that when ammonia combines directly with bodies that contain hydrogen, it may be considered as ammonium, replacing one atom of hydrogen, then we may consider Platosamine as an ammonioplatosammoniumoxyd, composed according to the following formula:

$$\left.\begin{matrix}H^2\\ H^4N\\ Pt\end{matrix}\right\} NO.HO.$$

I may remark that the tendency of bases to combine with a second equivalent of ammonia is frequently manifested in complex compounds." *Supplemente zum Handwörterbuche der Chemie*, 473. In this passage Hofmann adopts the notion, that ammonium ZH^4 can replace H^1 in ammonium, a notion which appears to me to be subversive of the very idea of an ammonium. I have not met with Mr. Graham's advocacy of this strange proposal.

The salt 42] has strong alkaline properties; its solution is nearly as corrosive as that of caustic soda; and it rapidly attracts carbonic acid from the atmosphere. The formula which I have given to it is equivalent to that of anhydrous soda:

ZH^4,ZH^3PtO = the salt No. 42].
$Na\ ,Na\quad O$ = anhydrous soda.

With hydrochloric acid, the salt 42] produces water and the chlorine compound 35]:

$$ZH^4;\ ZH^3PtO + HCl = (ZH^3Pt;\ Cl + ZH^2H) + HHO.$$

43]. $ZH^3Pt;\ SO^2$ = Platousam sulphete.

Formed by boiling Platousam ioda, No. 38] = ZH^3Pt,I, with aqueous sulphate of silver. Gmelin calls it Ammonio-sulphate of platinous oxide, with one atom of ammonia = $NH^3,PtO,SO^3 + HO$. He says that this water cannot be separated. In that case, the formula 43] should be $ZH^3Pt,SO^2 + \frac{1}{2}aq$. The salt reddens litmus strongly. By solution in ammonia, it is converted into No. 44]. Grimm describes it as Sulphate of platosamine = $(PtH^3)NO.SO^3$.

44]. $ZH^3Pt;\ SO^2 + ZH^2H$ = Platousam sulphete cum amida hydra.

The preparation is described in the note to 43]. It can also be prepared by adding strong sulphuric acid to Platousam chlora cum amida hydra, No. 35] = $ZH^3Pt; Cl + ZH^2H$. In the last case, the reaction falls entirely upon the chlorine of the salt:

$$Cl + HSO^2 = SO^2 + HCl.$$

The salt forms transparent square-based octahedrons, which have no action on vegetable colours. Gmelin calls it Ammonio-sulphate of platinous oxide, with two atoms of ammonia = $2NH^3,PtO,SO^3$. Grimm calls it Sulphate of ammon-platammoniumoxyd = $(H^4N,Pt,H^2)NO.SO^3$. Gerhardt's name is Sulphate of diplatosamine.

45]. $ZH^3Pt; NO^3$ = Platousam nitrite.

Formed by boiling Platousam ioda, 38] = $ZH^3Pt; I$, with aqueous silver nitrate ($AgNO^3$ = argenta nitrite). The reaction is simply a case of double decomposition:

$$ZH^3Pt; I + AgNO^3 = ZH^3Pt; NO^3 + AgI.$$

The solution of the crystallized salt reddens litmus strongly. It is converted, by solution in ammonia, into the salt No. 46]. Gmelin calls it Ammonio-Nitrate of platinous oxide, with one atom of ammonia = NH^3,PtO,NO^5. It is Gerhardt's Nitrate of platosamine = NH^3Pt, NHO^3. Sometimes called the Nitrate of Reiset's second base.

46]. $ZH^3Pt; NO^3 + ZH^2H$ = Platousam nitrite cum amida hydra.

This salt is prepared by acting upon platousam chlora cum amida hydra, No. 35] = $ZH^3Pt; Cl + ZH^2H$, either with nitrate of silver $AgNO^3$, or with nitric acid = HNO^3, when double decomposition ensues. Gmelin's name for this salt is Ammonio-nitrate of platinous oxide, with two atoms of ammonia = $2NH^3,PtO,NO^5$. It is Gerhardt's Nitrate of diplatosamine = N^2H^5Pt,NHO^3. Grimm's name is Nitrate of ammon-platammoniumoxyd = $(H^4N,Pt,H^2)NO.NO^5$. Miller calls it Nitrate of diplatosamine (Reiset's first base) = PtH^6N^2O,NO^5.

47]. $ZH^4; ZH^3Pt; CO^3$ = Ammona platousam carbite.

This formula represents a neutral carbonate, in which platousam and ammona form the two positive radicals. These radicals are the same as those which occur in the salt No. 42] = $ZH^4; ZH^3PtO$. It is formed when a solution of the salt No. 42] is exposed to a current of carbonic acid gas:

$$ZH^4; ZH^3PtO + CO^2 = ZH^4; ZH^3Pt; CO^3.$$

This salt is Gerhardt's Carbonate of diplatosamine, and Grimm's Carbonate of ammon-platammoniumoxyd = $(H^4N,Pt,H^2)NO.CO^2 + HO.CO^2$. This formula leads Grimm to call it the *acid salt*, and he allots the term *neutral salt* to the one which I have formulated in No. 48], so that, in my opinion, he misnames both.

$$48].\ \left\{\begin{matrix} ZH^4;\ ZH^3Pt;\ CO^3 \\ ZH^4;\ ZH^3PtO \end{matrix}\right\} = \begin{matrix}\text{Ammona platousam carbite} \\ \text{cum ammona platousamate.}\end{matrix}$$

or thus, as a tetrabasic salt:

$$(ZH^4)^2;\ (ZH^3Pt)^2;\ CO^4 \quad = \text{ Ammonen platousamen carbote.}$$

This salt is a compound of No. 47] with No. 42]. It is produced by exposing a solution of No. 42] to atmospheric air. Grimm's formula for the so-called neutral salt is $(H^4N,Pt,H^2)NO.CO^2 + HO$. He also notices a sesquicarbonate with the formula

$$2\left(\left.\begin{matrix} H^4N \\ Pt \\ H^2 \end{matrix}\right\} NO.CO^2\right) + HO.CO^2,$$

the occurrence of which is improbable. Miller, also, calls No. 47] Bicarbonate of diplatosamine (Reiset's first base) = $HO,PtH^6N^2O,2CO^2$.

It is worthy of remark, that a salt which, on the Radical theory, is a *bibasic neutral carbonate*, may, on the theory of "acids and bases," be represented as a *monobasic bicarbonate*.

$$49].\ ZH^3Pt;\ Cy \ = \text{ Platousam cyana.}$$

The cyanide of platousam. It is produced, in company with hydrocyanate of ammonia, by saturating the protoxide No. 42] with hydrocyanic acid (HCy = hydra cyana). Thus:

$$ZH^4;\ ZH^3Pt,O + H^2Cy^2 = ZH^4Cy + ZH^3Pt,Cy + HHO.$$

The products are platousam cyana, ammona cyana, and water. It is also produced by passing cyanogen gas through a solution of No. 42]. The separated oxygen gives rise to some secondary reactions. Buckton considers the most convenient method of production to be that of decomposing Platousam chlora No. 34] = $ZH^3Pt;\ Cl$ by Potassa cyana = KCy, which is a case of direct double decomposition:

$$ZH^3Pt,Cl + KCy = ZH^3Pt;\ Cy + KCl.$$

The decomposition of the salt No. 49] by nitrate of silver = AgNO, argenta nitrite, is as follows:—

$$\left.\begin{matrix} ZH^3Pt,Cy \\ ZH^3Pt,Cy \\ Ag,NO^3 \end{matrix}\right\} = \left\{\begin{matrix} ZH^3Pt;\ NO^3 + ZH^2H = \text{No. } 46]. \\ AgCy + PtCy \qquad = \text{No. } 10]. \end{matrix}\right.$$

Synonymes. Hydrocyanate of platosamine = $\left.\begin{matrix} H^2 \\ Pt \end{matrix}\right\} N.HCy$ and Cyanide of platosammonium = $\left.\begin{matrix} H^3 \\ Pt \end{matrix}\right\} N.Cy$, *Buckton*.

50]. $ZH^3Pt ; Cy + AgCy$ = Platousam cyana cum argenta cyana.
51]. $ZH^3Pt ; Cy + ZnCy$ = Platousam cyana cum zinca cyana.
52]. $ZH^3Pt ; Cy + CoCy$ = Platousam cyana cum cobaltous cyana.
53]. $ZH^3Pt ; Cy + NiCy$ = Platousam cyana cum niccolous cyana.

These are double cyanides, which differ from those that were described at Nos. 8] to 10] only by containing platousam instead of platous atoms. They are procured by the action of platinocyanide of potassium, No. 10], upon ammoniacal solutions of salts of the respective metals.

54]. ZH^3Pt,Cy,S^2 = Platousam cyana sulphene.

Buckton calls this salt the Platino-bisulphocyanide of diplatosammonium = $PtH^6N^2,Pt\,2(CyS^2)$. It is similar in constitution to the salt No. 13], excepting that it contains platousam instead of the platous atom; but Buckton doubles the constituents to make the salt agree with his double sulphocyanides, Nos. 14] and 15]. The unsupported notion that half the platinum is combined with the imaginary sulpho-cyanogen, and the other half with the ammonia, does not warrant the doubling of the formulæ.

55]. $ZH^4 ; ZH^3Pt ; S^2O^3$ = Ammona platousam sulphenite.

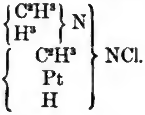
This sulphite, and the four compounds represented by Nos. 56] to 59], are produced by the action of sulphite of ammonia on the different modifications of platousam chlora, No. 34]. The compounds Nos. 56] and 57] are produced either by the red or the green salt; those represented by Nos. 58] and 59] are produced by the yellow salt. The comparison of these products with the various doubtful formulæ attributable to the salt 34] (see page 319), has not enabled me to clear away the difficulties which rest on this point.

60]. $ZH^3Pt ; Cl + ZH^3Cuc ; Cl$ = Platousam chlora cum cupricam chlora.

This salt is a double chloride of platousam and cupricam; that is to say, it contains chlorides of two vice-ammoniums, each of which contains one metallic atom in place of one atom of hydrogen. The salts Nos. 61] to 63] are of similar constitution. Buckton, who discovered these salts, describes them as compounds of chloride of diplatosammonium, No. 35], with chlorides of the respective metals. Thus, No. 60] is chloride of diplatosammonium combined with chloride of copper = $PtH^6N^2Cl,CuCl$, *Buckton*. See his Memoir, *Quarterly Journal of the Chemical Society*, v. 213. It is much more probable that they are double chlorides of ammonams, in agreement with formulæ 60 to 63].

64]. $ZH,CH^3,CH^3,Pt ; Cl + ZH^2H$ = Platous-methylem chlora cum amida hydra.

This salt differs from No. 35], only by having two atoms of methyl in the vice-ammon instead of H^2. Hofmann's name and formula for this salt are, Methylobiplatosammoniumchlorid = $C^4PtH^{10}N^2Cl$. Grimm calls it Methylammon-Methyl-Platammoniumchlorür, and he gives it this magnificent formula, which is recommended by a high degree of improbability. The existence of an ammonium within an ammonium is an assumption to which I can in no case agree.

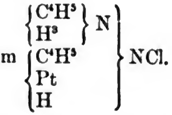


$$\left.\begin{array}{l}\left\{\begin{array}{l}C^2H^3\\ H^3\end{array}\right\}N\\ \left\{\begin{array}{c}C^2H^3\\ Pt\\ H\end{array}\right.\end{array}\right\}NCl.$$

65]. $ZH,C^4H^5,C^4H^5,Pt;Cl + ZH^2H$ = Platous-ethylem chlora cum amida hydra.

Similar to No. 64], excepting that it contains $(C^4H^5)^2$ instead of $(CH^3)^2$. Hofmann's name: Æthylobiplatosammoniumchlorid = $C^8PtH^{14}N^2Cl$. Grimm's name and formula:

Æthylammon-Æthyl-Platammonium



$$\left.\begin{array}{l}\left\{\begin{array}{l}C^4H^5\\ H^3\end{array}\right\}N\\ \left\{\begin{array}{l}C^4H^5\\ Pt\\ H\end{array}\right.\end{array}\right\}NCl.$$

66]. $ZH,C^6H^5,C^6H^5,Pt;Cl + ZH^2H$ = Platous-phenylem chlora cum amida hydra.

Similar to 64] and 65], but having two atoms of phenyl instead of H^2. Grimm's name is Phenylammon-Phenyl-Platammonium chlorür, with a five-line formula of similar architecture to the two that I have cited for Nos. 64] and 65], and liable to the same objection.

67]. $ZH^2,C^6H^5,Pt;\ Cl$ = Platous-phenylam chlora.

Similar in constitution to platousam chlora, No. 34], excepting that H^1 is replaced by C^6H^5. A salt of a violet colour. Discovered by Raewsky; said by him to correspond to the green salt of Magnus, and to be capable, like that salt, of assuming a variety of isomeric conditions. If that is the case, this compound may hereafter supply information which may lead to the accurate discrimination of the compounds that I have described in the note to No. 34].

68]. $ZH^3,C^6H^5;Cl + PtCl$ = Phenylam chlora cum platous chlora.

A garnet-coloured compound, discovered by Raewsky. Formula = $C^{12}H^7N,PtCl.HCl$, a form which, according to Hofmann, is not yet represented in the ammonia series.

Class IV.—Salts of Platicam = ZH^3Ptc.

70]. $ZH^3Ptc;\ Cl$ = Platicam chlora.

71]. $ZH^3Ptc;\ Cl + PtcCl$ = Platicam chlora cum platic chlora.

72]. $ZH^3Ptc;\ Cl + ZH^4Ptc;\ Br$ = Platicam chlora cum platicam broma.

73]. $ZH^3Ptc;\ Cl + ZH^3Ptc;\ SO^2$ = Platicam chlora cum platicam sulphete.

74]. $ZH^3Ptc;\ Cl + ZH^3Ptc;\ CO^2$ = Platicam chlora cum platicam carbete.

75]. $ZH^3Ptc;\ Cl + ZH^3Ptc;\ NO^3$ = Platicam chlora cum platicam nitrite.

77]. $ZH^3Ptc;\ Cl + (ZH^3Ptc)^3PO^4$ = Platicam chlora cum platicamine phosphote.

78]. $ZH^3Ptc;\ NO^3 + ZH^3Ptc;\ CO^2$ = Platicam nitrite cum platicam carbete.

80]. $ZH^3Ptc;\ HO + PtcHO$ = Platicam hydrate cum platic hydrate.

81]. $ZH^3Ptc;\ SO^2 + PtcSO^2$ = Platicam sulphete cum platic sulphete.

82]. $ZH^3Ptc;\ NO^3 + PtcNO^3$ = Platicam nitrite cum platic nitrite.

83]. $ZH^3Ptc;\ NO^3 + PtcHO + aq$ = Platicam nitrite cum platic hydrate aquate.

84]. $\left\{\begin{array}{l} ZH^3Ptc;\ CO^2 \\ Ptc\quad;\ HO \end{array}\right\} + \frac{1}{2}\ aq$ = Platicam carbete cum platic hydrate demi-aquate

85]. $\left\{\begin{array}{l} ZH^3Ptc;\ Cl \\ (ZH^3Ptc;\ NO^3)^2 \\ ZH^4;\ PtcO \end{array}\right\}$ = Platicam chlora bis platicam nitrite cum ammona platicate.

86]. $\left\{\begin{array}{l} ZH^3Ptc;\ Cl \\ (ZH^3Ptc)^2;\ CO^3 \\ ZH^4;\ PtcO \end{array}\right\}$ = Platicam chlora cum platicamen carbite cum ammona platicate.

87]. $\left\{\begin{array}{l} ZH^3Ptc;\ NO^3 \\ ZH^4;\ PtcO \end{array}\right\}$ = Platicam nitrite cum ammona platicate.

88]. $\left\{\begin{array}{l} (ZH^3Ptc;\ NO^3)^3 \\ ZH^4;\ PtcO \end{array}\right\}$ = Tris platicam nitrite cum ammona platicate.

89]. $\left\{\begin{array}{l} ZH^3Ptc;\ NO^3 \\ (ZH^3Ptc;\ CO^3)^2 \\ ZH^4;\ PtcO \end{array}\right\}$ = Platicam nitrite bis platicam carbete cum ammona platicate.

90]. $ZH^2,C^6H^5,Ptc;\ Cl$ = Platic-phenylam chlora.

91]. $ZH^2,C^2H^5,C^6H^5; Cl + 2PtcCl$ = Phenylic - ethylam chlora bis platic chlora.
92]. $ZH,C^2H^5,C^2H^5,C^6H^5; Cl + 2PtcCl$ = Phenylic-ethylem chlora bis platic chlora.
93]. $Z(C^2H^5)^2,C^6H^5; Cl + 2PtcCl$ = Phenylic-ethylim chlora bis platic chlora.
94]. $ZH^2,CH^3,C^6H^5; Cl + 2PtcCl$ = Phenylic-methylam chlora bis platic chlora.
95]. $ZCH^3,C^2H^5,C^5H^{11},C^6H^5; Cl + 2PtcCl$ = Zot-methyla-ethyla-amyla-phenyla chlora bis platic chlora.
96]. $Z,(CH^3)^4,Cl + 2PtcCl$ = Methylom chlora bis platic chlora.
97]. $Z(C^2H^5)^4,Cl + 2PtcCl$ = Ethylom chlora bis platic chlora.
98]. $Z(C^5H^{11})^4,Cl + 2PtcCl$ = Amylom chlora bis platic chlora.
99]. $\left\{\begin{matrix} ZC^2H^5,C^6H^5; NO^3 \\ H,Ptc^2; Cl^3 \end{matrix}\right\}$ = Ethylic - phenylac nitrete cum hydra platenic chlorine.
100]. $ZH^2,C^2H^3,C^6H^5; Cl + 2PtcCl$ = Phenylic - acetylam chlora bis platic chlora.

USUAL NAMES AND FORMULÆ OF THE SALTS OF PLATICAM.

70]. $ZH^3Ptc; Cl$ = Platicam chlora.

This salt is produced by the action of sesquichloride of iron = $FecCl$, on the salt No. 35] = $ZH^3Pt; Cl + ZH^3H$. See the note descriptive of No. 35]. It is also produced by the action of chlorine gas on the same salt:

$$ZH^3Pt; Cl + ZH^3H + Cl = ZH^3Ptc; Cl + ZH^3Ptc; Cl.$$

There are many other methods of obtaining it. It is produced whenever basic power is removed from a salt of platousam and chloric power applied instead. Pt^1 then becomes Ptc^2. Also produced by boiling No. 71] with ammonia, and by acting on No. 75] with strong hydrochloric acid.

Synonymes.—Ammonio-bichloride of platinum = $2NH^3,PtCl^2$, *Gmelin.* Bihydrochlorate of diplatinamine = $N^2H^4pt^2,2HCl$, *Gerhardt.* Ammonchlorplatammoniumchlorür = $(H^4N,PtCl,H^2)NCl$, or else

$$\left\{\begin{matrix} \left.\begin{matrix} H^3 \\ PtCl \end{matrix}\right\} N \\ H^3 \end{matrix}\right\} NCl,$$ *Grimm.*

Miller quotes a hydrochlorate of diplatinamine with the formula PtH^3N^2,Cl. I can find no account of such a salt. Miller also quotes the hydrochlorate of Gros's base, with the formula $PtClH^6N^2Cl$. This agrees with No. 70]. Gros's base he gives as $PtClH^6N^2O$, *not isolated.* The nitrate of Gros's base is No. 75].

71]. $ZH^3Ptc; Cl + PtcCl$ = Platicam chlora cum platic chlora.

This salt is produced by the action of chlorine on Magnus's green salt, No. 34] = $ZH^3Pt; Cl$. The chloric power converts Pt^1 into Ptc^2, and then produces the salt No. 71]. According to Gerhardt, there is an intermediate salt produced, in the form of a red crystalline power, which appears to be a compound of Nos. 34] and 71]. Thus, $ZH^3Pt,Cl + (ZH^3Ptc; Cl + PtcCl)$. He calls it chloroplatinate of diplatosamine.

Gerhardt's name and formula for No. 71] are Bichlorhydro-chloroplatinate of diplatinamine = $\left\{\begin{matrix} PtCl^3H \\ ClH \end{matrix}\right\} N^2H^4pt^2$. Grimm's name and formula = Ammon-chlorplatammoniumchlorür-platinchlorid = $(H^4N, PtCl,H^2)NCl + PtCl^2$. Ammonio-bichloride of platinum = $NH^3,PtCl^2$, *Gmelin*. Bi-hydrochlorate of platinamine = $NHpt^2,2HCl$, *Gerhardt*. Miller's name and formula are Bihydrochlorate of platinamine (Gerhardt's base) = PtH^3N,Cl^2.

Gerhardt makes a distinction between the products of the action of chlorine gas upon solutions of the yellow and the green variety of platousam chlora, No. 34]; and hence the different names and formulæ which I have ascribed to him. The analytical results of the different products are the same; excepting that one salt is anhydrous, and the other, when dried at 120° C, retains about two per cent. of water. In other respects the evidence of differences in these products is not sufficiently clear to remove any of the difficulties that have been described in the note appended to No. 34].

72]. $ZH^3Ptc; Cl + ZH^3Ptc; Br$ = Platicam chlora cum platicam broma.

Produced by adding bromine to the salt No. 35] = $ZH^3Pt; Cl + ZH^3H$. In this case Pt^1 becomes Ptc^2, bromine is assumed, and thus the salt 72] is formed. It has an orange-yellow colour, and its solution gives with silver-solution a precipitate containing AgCl and AgBr.

The production of this salt affords clear evidence in support of the opinion which I have expressed, that in the presence of an excess of chloric, bromic, or iodic power, the platous atom becomes converted into platic atoms.

Synonymes. Ammonio-chlorobromide of platinum = $2NH^3,PtClBr$, *Gmelin.* Ammon-Bromplatammoniumchlorür = $Pt(Cl,Br)N^2H^6$ = $(H^4N,PtBr,H^2)NCl$, *Grimm.*

73]. $ZH^3Ptc; Cl + ZH^3Ptc; SO^2$ = Platicam chlora cum platicam sulphete.

Produced when the salt No. 70] is dissolved in strong sulphuric acid and heated to drive off muriatic acid:

$$2(ZH^3Ptc\,;\,Cl) + HSO^4 = ZH^3Ptc\,;\,Cl + ZH^3Ptc\,;\,SO^4 + HCl.$$

It is also produced when the salt No. 75] is heated with sulphuric acid, in which case nitric acid is driven off.

Synonymes. Ammonio-sulphate of oxychloride of platinum = $2NH^3, PtClO,SO^3$, *Gmelin.* Bichlorhydro-sulphate of diplatinamine = $N^2H^4pt^2, SO^4H^2 + N^2H^4pt^2,2ClH$, *Gerhardt.* Gros's sulphate. Sulphate of Ammon-chlorplatammoniumoxyd = $(H^4N,PtCl,H^2)NO.SO^3$, *Grimm.*

74]. $ZH^3Ptc\,;\,Cl + ZH^3Ptc\,;\,CO^2$ = Platicam chlora cum platicam carbete.

Produced by adding oxalic acid to the solution of the salts Nos. 73] or 75], *Gros.*

Synonymes. Ammonio-chloroplatinous oxalate. Ammonio-oxalate of oxychloride of platinum = $4NH^3 + C^4(PtCl)^2O^8$, *Gmelin.* Bichlorhydro-oxalate of diplatinamine = $\left.\begin{matrix} C^2H^2O^4 \\ 2ClH \end{matrix}\right\} 2N^2H^4pt^2$, *Gerhardt.* Oxalate of Ammon-chlorplatammoniumoxyd = $(H^4N,PtCl,H^2)NO.C^2O^3$, *Grimm.*

75]. $ZH^3Ptc\,;\,Cl + ZH^3Ptc\,;\,NO^3$ = Platicam chlora cum platicam nitrite.

Produced by the action of nitric acid on the salt No. 34]—Magnus's green salt—thus:

$$\left.\begin{array}{r} ZH^3Pt\,;\,Cl \\ ZH^3Pt\,;\,Cl \\ H\,;\,NO^3 \end{array}\right\} = \left\{\begin{array}{l} ZH^3Ptc\,;\,Cl + ZH^3Ptc\,;\,NO^3 \\ Pt, \textit{half the platinum thrown down}, \\ HCl\ \textit{set free}, \qquad\qquad \textit{Gros.} \end{array}\right.$$

Synonymes. Ammonio-nitrate of oxychloride of platinum = $2NH^3, PtClO,NO^5$, *Gmelin.* Bichlorohydro-nitrate of diplatinamine = $N^2H^4pt^2, NHO^3,ClH$, *Gerhardt.* Nitrate of Ammon-chlorplatammoniumoxyd = $(H^4N,PtCl,H^2)NO.NO^5$, *Grimm.* Nitrate of Gros's base = $PtClH^6N^2O, NO^5$, and also $(PtCl,2H^3N,O)NO^5$, *Miller.*

"Gerhardt," says Professor Miller (*Elements of Chemistry*, part ii., 1066), "views the salts of Gros as biacid salts of diplatinamine, in some of which two acids are present. A serious objection to this supposition, however, is afforded by the fact that Gros's hydrochlorate abandons only half its chlorine when mixed with the solution of nitrate of silver. It ought to give up the whole were Gerhardt's theory correct."

Professor Miller's difficulty does not exist in the facts, but in the erroneous theory which guides his reasoning. If I were to ask him to explain WHY nitrate of silver, acting upon the salt No. 70], *ought* to throw down *all* the chlorine? the reply would, no doubt, be, that it is, or rather should be, simply a case of double decomposition. ZH^3Ptc ;

$Cl + AgNO^3 = AgCl + ZH^3Ptc; NO^6$. That reaction does not indeed take place, but the cause of the different reaction that really takes place is obvious. Thus:

$$\left.\begin{array}{r} ZH^3Ptc; Cl \\ ZH^3Ptc; Cl \\ Ag; NO^3 \end{array}\right\} = \left\{\begin{array}{c} \left.\begin{array}{r} ZH^3Ptc; Cl \\ ZH^3Ptc; NO^6 \end{array}\right\} \text{No. 75.} \\ Ag; Cl \end{array}\right.$$

This reaction is precisely analogous to that which takes place in the preparation of No. 75], by adding nitric acid to No. 34], and to that which occurs in the preparation of No. 73]. When the double salt No. 75] is produced, it resists decomposition by nitric acid, by nitrate of silver, and even by sulphuric acid. That is the solution of the problem.

77]. $ZH^3Ptc; Cl + (ZH^3Ptc)^3PO^4$ = Platicam chlora cum platicamine phosphote.

Synonymes. Sesquichlorhydro-phosphate of diplatinamine = $N^2H^4pt^2, PO^4H^3 + N^2H^4pt^2,ClH$, *Gerhardt*. Phosphate of Ammon-Chlorplatammoniumoxyd and Ammon-Oxyplatammoniumoxyd

$$= \left[\left.\begin{array}{c} H^4N \\ PtCl \\ H^2 \end{array}\right\} NO, \left\{\begin{array}{c} H^4N \\ PtO \\ H^2 \end{array}\right\} NO,HO\right] + PO^5 + HO, \textit{Grimm.}$$

Phosphate of Raewsky's base = $Pt^2ClH^{12}N^4O^5,PO^5,HO$, *Miller*.

78]. $ZH^3Ptc; NO^3 + ZH^3Ptc; CO^2$ = Platicam nitrite cum platicam carbete.

A combination of nitrate of platicam with oxalate of platicam.

Synonymes. Binitro-oxalate of diplatinamine = $N^2H^4pt^2,C^2H^2O^4 + N^2H^4pt^2,2NHO^3$

$$= \left\{\begin{array}{r} C^4H[NHpt^2(NH^4)]O^8 \\ NHO^6 \\ N[NHpt^2(NH^4)]O^6 \end{array}\right\} \begin{array}{l} \text{Bioxalate of diplatinammonium} \\ \text{Nitric acid} \\ \text{Nitrate of diplatinammonium} \end{array}$$

$$= 2C^2O^3,2NO^5,2PtO^2,4NH^3.$$

All these formulæ are given by Gerhardt. They are striking examples of the exercise of the ingenious art of giving apparent complexity to things which are naturally simple.

80]. $ZH^3Ptc; HO + PtcHO$ = Platicam hydrate cum platic hydrate.

Produced by adding an excess of ammonia to a boiling solution of nitrate of platinamine No. 83]. Small brilliant yellow crystals. Caustic potash does not dissolve it, nor expel ammonia from it (because caustic potash and this compound are both hydrated basic radicals of the same order). It readily dissolves in acids.

Synonymes. Platinamine = $NHpt^2 + 2Aq$, *Gerhardt.* Oxyplatammoniumoxydhydrate = $(PtO,H^3)NO.HO + HO$, *Kolbe.* Platinamine = $NH^3,PtO^2 + 2Aq$, *Gmelin.* Miller ascribes to Platinamine (Gerhardt's base) the formula PtH^3N,O^2, which in my notation would be either ZH^3PtO, or $ZH^3Ptc,PtcO$; but no such compound appears to have been produced. Gerhardt's Platinamine requires the formula that is given to No. 80].

81]. $ZH^3Ptc\,;\ SO^2 + PtcSO^2$ = Platicam sulphete cum platic sulphete.

Produced by dissolving platinamine, No. 80] in sulphuric acid. Yellow powder; acid; soluble.

Synonymes. Sulphate of platinamine = $NH^3,PtO^2,2SO^3$, *Gmelin.* Bisulphate of platinamine = $NHpt^2,SO^4H^2$, *Gerhardt.*

82]. $ZH^3Ptc\,;\ NO^3 + PtcNO^3$ = Platicam nitrite cum platic nitrite.

Produced by mixing nitric acid with No. 83], and evaporating. A yellow powder.

Binitrate of platinamine = $NH^3,PtO^2,2NO^5$, *Gmelin.* Binitrate of platinamine = $NHpt^2,2HNO^3$, *Gerhardt.* Binitrate of platinamine = $PtH^3N,O^2,2NO^5$, *Miller.*

83]. $ZH^3Ptc\,;\ NO^3 + PtcHO + HHO$ (dried at 120° C) = Platicam nitrite cum platic hydrate aquate.

Produced by boiling the chloride No. 71] with nitrate of silver, until the chlorine is wholly abstracted by the silver.

Synonymes. Neutral nitrate of platinamine = $NHpt^2,NHO^3 + 2\,aq$, *Gerhardt.* Ammonio-nitrate of platinic oxide = $NH^3,PtO^2,NO^5 + 3\,aq$, *Gmelin.* Nitrate of Oxyplatammoniumoxyd = $(PtO,H^3)NO.NO^5 + 3HO$, *Grimm.* Neutral nitrate of platinamine = $PtH^3N,O^2,NO^5\ 3HO$, *Miller.*

84]. $\left\{\begin{array}{l} ZH^3Ptc\,;\ CO^2 \\ Ptc\quad\ \ ;\ HO \end{array}\right\} + \frac{1}{2}\,aq$ = Platicam carbete cum platic hydrate demi-aquate.

Produced by adding oxalate of ammonia to No. 83]. Yellow crystals which explode when heated. This is Gerhardt's neutral oxalate of platinamine = $C^2H^2O^4,2NHpt^2 + 3Aq$.

[*Query*—DOES PLATICCEM OCCUR AS A RADICAL AMONG THE PLATINUM SALTS?

PLATICCEM is the vice-ammon = ZH^2Ptc^2, produced by replacing H^2 in ammonium by two platic atoms. The five salts Nos. 80] to 84] can be conveniently formulated with such a radical. Thus:

No. 80 = $ZH^2Ptc^2\,;\ HO + Aq$. Platiccem hydrate aquate.

81 = $\mathrm{ZH^2Ptc^2;\ SO^2 + HSO^2}$. Platiccem sulphete cum hydra sulphete.
82 = $\mathrm{ZH^2Ptc^2;\ NO^3 + HNO^3}$. Platiccem nitrite cum hydra nitrite.
83 = $\mathrm{ZH^2Ptc^2;\ NO^3 + Aq^2}$. Platiccem nitrite aquete.
84 = $\mathrm{ZH^2Ptc^2;\ CO^2 + 1\frac{1}{2}\,Aq}$. Platiccem carbete sesquiaquate.

These are the principal salts of the series to which Gerhardt ascribes his "platinamine," which may hereafter be proved to be *platiccem*, although our present information is not conclusive on that point.]

$$85].\ \left\{\begin{array}{l}\mathrm{ZH^3Ptc;\ Cl}\\ \mathrm{(ZH^3Ptc;\ NO^3)^2}\\ \mathrm{ZH^4;\ PtcO}\end{array}\right\} = \text{Platicam chlora bis platicam nitrite cum ammona platicate.}$$

Produced by the action of concentrated nitric acid on Magnus's green salt, No. 34], *Raewsky*, whose formula is $\mathrm{4NH^3,Pt^2ClO^5,2NO^5}$. Produced by the action of nitrate of silver upon the salt No. 70]. Brilliant yellow small hard rhombic crystals, which explode when heated.

The property of exploding when heated is apparently concurrent with the presence of the compound $\mathrm{ZH^4;\ PtcO}$. The salts which, in combination with $\mathrm{ZH^4;\ PtcO}$, compose the compounds Nos. 85 to 89, that is to say, the chloride, nitrate, carbonate, and oxalate of platicam, do not seem to be explosive either when isolated or when combined in pairs, provided the salt $\mathrm{ZH^4;\ PtcO}$ is absent. But when this salt forms part of a compound, the compound is explosive. It is on account of this peculiarity that I prefer the formula $\mathrm{ZH^4;\ PtcO}$ to the formula $\mathrm{ZH^3Ptc;\ HO}$, which would make the several salts appear as basic salts. But the formulæ of these salts, as given by different chemists, are by no means concurrent even as regards the ultimate constituents of the salts, and while uncertainty prevails on that score, no satisfactory analytical formulæ can be written.

Synonymes. Ammonio-binitrate of oxychloride of platinum, *Gmelin.* Sesquichlorhydronitrate of diplatinamine = $\mathrm{N^2H^4pt^2,2NHO^6 + N^2H^4pt^2,ClH}$, *Gerhardt.* Double Nitrate of Ammon-Chlorplatammoniumoxyd and Ammon-Oxyplatammoniumoxyd = $\mathrm{(H^4N,PtCl,H^2)NO.NO^5 + (H^4N,PtO,H^2)NO.NO^5 + HO}$, *Grimm.* Binitrate of Raewsky's base = $\mathrm{Pt^2ClH^{12}N^4O^5,2NO^5}$, *Miller.*

$$86].\ \left\{\begin{array}{l}\mathrm{ZH^3Ptc;\ Cl}\\ \mathrm{(ZH^3Ptc)^2;\ CO^3}\\ \mathrm{ZH^4;\ PtcO}\end{array}\right\} = \text{Platicam chlora cum platicamen carbite cum ammona platicate.}$$

Synonymes.—Raewsky's ammonio-carbonate of oxychloride of platinum = $\mathrm{4NH^3,Pt^2ClO^5,2CO^2}$, *Gmelin.* Sesquichlorhydro-carbonate of diplatinamine = $\mathrm{N^2H^4pt^2,CO^3H^2 + N^2H^4pt^2,ClH + Aq}$, *Gerhardt.* Carbonate of ammon-chlorplatammoniumoxyd and of ammon-oxyplatammoniumoxyd = $(H^4N,PtCl,H^2)NO.CO^2 + (H^4N,PtO,H^2)NO.CO^2 + HO$, *Grimm.*

87]. $\left\{\begin{matrix} ZH^3Ptc\,;\ NO^3 \\ ZH^4\,;\ PtcO \end{matrix}\right\} =$ Platicam nitrite cum ammona platicate.

Synonymes.—Ammonio-nitrate of platinic-oxide = $2NH^3,PtO^2,NO^5 + Aq$, *Gmelin.* Neutral nitrate of diplatinamine = $N^2H^4pt^2,NHO^6 + Aq$, *Gerhardt.* Neutral nitrate of ammon-oxyplatammoniumoxyd = $(H^4N,PtO,H^2)NO.NO^5 + HO$, *Grimm.* Neutral nitrate of diplatinamine = $PtH^6N^2O^2,NO^5,HO$, *Miller.*

88]. $\left\{\begin{matrix} (ZH^3Ptc\,;\ NO^3)^3 \\ ZH^4\,;\ PtcO \end{matrix}\right\} =$ Tris platicam nitrite cum ammona platicate.

Synonymes.—Ammonio-sesquinitrate of platinic oxide = $4NH^3,2PtO^2,3NO^5 + Aq$, *Gmelin.* Sesquinitrate of diplatinamine = $2N^2H^4pt^2,3NHO^6 + Aq$, *Gerhardt.* Neutral nitrate of ammon-oxyplatammoniumoxyd = $(H^4N,PtO,H^2)NO.NO^5 + HO$, *Grimm.* Sesquinitrate of diplatinamine = $2(PtH^6N^2O^2),3NO^5,HO$, *Miller.*

89]. $\left\{\begin{matrix} ZH^3Ptc\,;\ NO^3 \\ (ZH^3Ptc\,;\ CO^2)^2 \\ ZH^4\,;\ PtcO \end{matrix}\right\} =$ Platicam nitrite bis platicam carbete cum ammona platicate.

Synonymes.—Sesquinitro-oxalate of diplatinamine

$$= \left\{\begin{matrix} C^4H[NHpt^2(NH^4)]O^8 \\ \\ N[NHpt^2(NH^4)]O^6 \end{matrix}\right\} \begin{matrix} \text{Bioxalate of diplatinammonium} \\ +\ 2\ \text{aq.} \\ \text{Nitrate of diplatinammonium} \end{matrix}$$

= $2C^2O^3,NO^5,2PtO^2,4NH^3,HO$, *Gerhardt.* Compare this formula with that quoted in the note to No. 78]. Grimm calls this compound Oxalate of ammon-oxyplatammoniumoxyd with nitric acid

$$= 2\left(\left.\begin{matrix} H^4N \\ PtO \\ H^2 \end{matrix}\right\} NO.C^2O^3\right) + HO.NO^5.$$

Grimm quotes the following as Gerhardt's formulæ :—

$$\left\{\begin{matrix} C^4H^2O^8\ .\ N^2H^4pt^2 \\ NHO^6\ \ .\ N^2H^4pt^2 \end{matrix}\right\} + 2\ \text{aq.}$$

90]. $ZH^2,C^6H^5,Ptc\,;\ Cl$ = Platic-phenylam chlora.

A rose-red salt, discovered by Raewsky. Formula quoted by Hofmann: $2(C^{12}H^7N),PtCl^2$. This salt is said to be produced by acting upon

No. 67] with hydrochloric acid; but other compounds must be formed simultaneously, because this statement leaves H + Ptc unaccounted for.

91]. ZH^2,C^2H^5,C^6H^5; Cl + 2PtcCl = Phenylic-ethylam chlora bis platic chlora.

Synonyme—Ethylaniline-platinchloride = $C^{12}\left\{\begin{matrix}H^6\\C^4H^5\end{matrix}\right\}N,HCl + PtCl^2$, *Hofmann.* Chlorplatin-salzsaures vinanilin = $C^{16}NH^{11},HCl + PtCl^2$, *Gmelin.*

92]. ZH,C^2H^5,C^2H^5,C^6H^5; Cl + 2PtcCl = Phenylic-ethylem chlora bis platic chlora.

Synonymes. Biethylaniline-platinchloride = $C^{20}H^{15}N.HCl.PtCl^2$, *Hofmann.* Chlorplatin-salzsaures bivinanilin = $C^{20}NH^{15},HCl + PtCl^2$, *Gmelin.*

93]. $Z(C^2H^5)^3,C^6H^5$; Cl + 2PtcCl = Phenylic-ethylim chlora bis platic chlora.

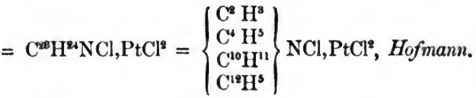
Synonymes. Chlorplatin-salzsaures trivinanilin = $C^{24}NH^{19},HCl + PtCl^2$ (equal to Hofmann's $C^{12}H^5(C^4H^5)^3NCl,PtCl^2$), *Gmelin.*

94]. ZH^2,CH^3,C^6H^5; Cl + 2PtcCl = Phenylic-methylam chlora bis platic chlora.

Synonymes. Methylaniline-platinchloride = $C^{12}(H^6,C^2H^3)N,HCl + PtCl^2$, *Hofmann.*

95]. $ZCH^3,C^2H^5,C^5H^{11},C^6H^5$; Cl + 2PtcCl = Zot-methyla-ethyla-amyla-phenyla chlora bis platic chlora.

Synonyme. The platinum-salt of methylethylamylphenylammonium



$$= C^{28}H^{24}NCl,PtCl^2 = \left\{\begin{matrix}C^2\,H^3\\C^4\,H^5\\C^{10}H^{11}\\C^{12}H^5\end{matrix}\right\}NCl,PtCl^2,\ \textit{Hofmann.}$$

96]. $Z(CH^3)^4$,Cl + 2PtcCl = Methylom chlora bis platic chlora.

Synonyme. The hydrochlorate of tetramethylammonium combined with bichloride of platinum

$$= C^8H^{12}NCl,PtCl^2 = \left\{\begin{matrix}C^2H^3\\C^2H^3\\C^2H^3\\C^2H^3\end{matrix}\right\}NCl,PtCl^2,\ \textit{Hofmann.}$$

97]. $Z(C^2H^5)^4$; Cl + 2PtcCl = Ethylom chlora bis platic chlora.

Synonyme. The platinum-salt of tetrethylammonium

$$= C^{16}H^{20}NCl,PtCl^2 = \left\{\begin{matrix} C^4H^5 \\ C^4H^5 \\ C^4H^5 \\ C^4H^5 \end{matrix}\right\} NCl,PtCl^2, \textit{Hofmann.}$$

98]. $Z(C^5H^{11})^4$; Cl + 2PtcCl = Amylom chlora bis platic chlora.

Synonyme. The platinum-salt of tetramylammonium

$$= C^{40}H^{44}NCl,PtCl^2 = \left\{\begin{matrix} C^{10}H^{11} \\ C^{10}H^{11} \\ C^{10}H^{11} \\ C^{10}H^{11} \end{matrix}\right\} NCl,PtCl^2, \textit{Hofmann.}$$

99]. $\left\{\begin{matrix} ZC^2H^5,C^6H^5;\ NO^2 \\ H,\ Ptc^2;\ Cl^3 \end{matrix}\right\} =$ Ethylic-phenylac nitrete cum hydra platenic chlorine.

Synonyme. Ethylnitranilin-platinchloride

$$= C^{12}\left\{\begin{matrix} H^5 \\ NO^4 \\ C^4H^5 \end{matrix}\right\} N,HCl + PtCl^2, \textit{Hofmann.}$$

Dr. Hofmann's "nitraniline" theory is discussed at page 288. The possibility of the existence of such an ammonium as is here represented, is inadmissible:

$$C^{12}\left\{\begin{matrix} H^5 \\ NO^4 \\ C^4H^5 \end{matrix}\right\} N,H.$$

100]. ZH^2,C^2H^3,C^6H^5; Cl + 2PtcCl = Phenylic-acetylam chlora bis platic chlora.

Synonyme. Chloroplatinate of phenyl-acetosamine = $C^4H^4(C^{12}H^5)N,HCl,PtCl^2$, *Gerhardt.*

The Urea Theory.

Non-Permanent Cyanate of Ammonia.—When the vapour of hydrated cyanic acid (= H,CyO) is passed into dry ammonia gas (= ZH^2,H), we obtain a white voluminous crystalline powder, which chemists in general agree in calling Cyanate of Ammonia, and the composition of which is stated to be H^4NO,C^2NO (= ZH^4,CyO). This powder is very soluble in water, and its cold solution, when freshly prepared, has the following properties:—

1. It disengages ammonia on the addition of a cold solution of caustic potash: $ZH^4CyO + KHO = ZH^2H + KCyO + HHO$.

2. When treated with acids, it gives off cyanic acid (*a*) and carbonic acid (*b*).

$$(a).\ ZH^4,CNO + H,SO^2 = ZH^4,SO^2 + H,CNO.$$

$$(b).\ \left.\begin{array}{r} ZH^4,CNO + H,HO \\ H,SO^2 + H,SO^2 \end{array}\right\} = \left\{\begin{array}{c} 2(ZH^4,SO^2) \\ CO^2 \end{array}\right.$$

The first reaction is simply a case of double decomposition between the cyanate of ammonia and the hydrated sulphuric acid. The second reaction is owing to the circumstance, that hydrated cyanic acid is readily decomposable by water into carbonic acid and ammonia:

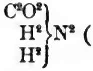
$$H,CNO + H,HO = ZH^2,H + CO^2.$$

This transformation is accelerated when a strong acid is present, which can take up the ammonia and expel the carbonic acid as gas:

$$ZH^2,H + HSO^2 = ZH^4,SO^2.$$

In equation (*b*), these two reactions are represented as occurring simultaneously.

Permanent Cyanate of Ammonia.—When the solution of cyanate of ammonia has been prepared two or three days; or when, soon after being prepared, it is either boiled or gently evaporated to the crystallising point; or when the white powder, described above, is exposed for some days to the air, or is slightly fused, before being brought into solution; then the resulting solution is found to contain a substance which is possessed of other properties than those above described, and this substance has received from chemists the name of Urea with the clump formula $C^2H^4N^2O^2$ (= CH^4N^2O) and sometime that of Carbamide, first with the formula $NH^2 + CO$, and latterly with the formula



$$\left.\begin{array}{r} C^2O^2 \\ H^2 \\ H^2 \end{array}\right\}N^2\ (= ZH^2,ZH^2,CO).$$

Berzelius represented it as a conjugated ammonia compound, having the formula NH^3,C^2HNO^2, to which he gave the name of urenoxyd-ammonia; but this notion has not been adopted by other chemists.

UREA THEORY.—Before I enter upon the examination of the properties that are said to distinguish Urea from the non-permanent Cyanate of Ammonia, I may state that I consider the composition of the two substances to bear to one another the same relation as that which is borne by the gaseous salts of ammonia to the solid salts of ammonium. See page 197. The non-permanent cyanate of ammonia, which is produced by the action of hydrated cyanic acid upon gaseous ammonia, is a double salt, constituted in accordance with the formula $ZH^2, H + H,CyO$, while the permanent salt, into which it so soon changes, is the true cyanate of ammonium, constituted according to the formula ZH^4,CyO. The names of the two substances should be, in agreement with this idea, as follow:

$ZH^2,H + H,CyO$ = Amida hydra cum hydra cyanate.
ZH^4,CyO = Ammona cyanate.

The supposition that urea should be esteemed to be *carbamide* $= ZH^2,ZH^2,CO$, is not well sustained by facts, as I have shown in the preceding pages, particularly in the arguments respecting the Nitriles, page 217; Carbamide, page 221; the Imides, page 222; Anilo-urea and Carbanilide, page 298, and in treating of various other compounds of minor importance.

CHEMICAL REACTIONS OF UREA.—I proceed to show that the best-known chemical reactions of Normal Urea (No. 1 in the table of examples at page 349), and the Compound Ureas (Nos. 2 to 18), justify the theory which is now advanced.

1. "Neither cyanic acid nor ammonia can be discovered in urea, but if a solution containing a mixture of nitrate of silver and urea be boiled for some time, it is partly resolved into cyanate of silver and nitrate of ammonia." Miller (*Elements of Chemistry*, iii. 609).

This argument and illustration are ill-adjusted to one another. The decomposition, when completed, is as follows:

$$ZH^4,CyO + Ag,NO^3 = ZH^4,NO^3 + Ag,CyO.$$

If urea is converted by nitrate of silver into *cyanate* of silver and nitrate of *ammonia*, however slowly the operation proceeds, surely there *is* a "discovery," both of cyanic acid and of ammonia in that salt, for neither of these compounds are contained in the nitrate of silver. Besides, we are told by Liebig and Wöhler, that if the mixture of the two salts is evaporated to dryness, the transformation is perfect. Hence the opinion, so frequently expressed by chemists, that "neither cyanic acid nor ammonia can be discovered in urea," is unwarranted by experimental facts.

2. A cold solution of urea mixed with a cold solution of caustic potash does not liberate ammonia. This is the experiment which distinguishes urea from the non-permanent cyanate of ammonia, which, under these circumstances, gives off ammonia. But it is a prodigious jump from this characteristic (which is explained at page 342) to the statement that "ammonia cannot be discovered in urea."

3. A complete decomposition of urea occurs when it is fused with hydrate of potash; the products being carbonate of potash and gaseous ammonia:

$$\left.\begin{array}{r} ZH^4,CNO \\ K,HO \\ K,HO \end{array}\right\} = \left\{\begin{array}{l} KK,CO^3 = \text{Carbonate of potash.} \\ \left.\begin{array}{l} ZH^2,H \\ ZH^2,H \end{array}\right\} = \text{Ammonia.} \end{array}\right.$$

Here the potassium carries off the carbon and oxygen, while the nitrogen produces amids, and ultimately ammonias, with the hydrogen.

4. One atom of permanent cyanate of ammonia (urea) heated in a sealed tube, with two atoms of water, produces one atom of carbonate of ammonia:

$$ZH^4,CNO + HHO,HHO = ZH^4,ZH^4 ; CO^3.$$

At pages 219 and 220 I have fully explained the theory of this reaction.

5. When urea is fused, it gives off ammonia gas, and leaves cyanuric acid:

$$ZH^4,CyO = ZH^2,H + H,CylO.$$

When the heat is increased, the cyanuric acid volatilises as cyanic acid. If this meets in the apparatus with gaseous ammonia, it again produces the non-permanent variety of cyanate of ammonia = $ZH^2,H + H,CyO$, in the form of a white powder. This is often referred to as being a sublimate of undecomposed urea. Of course, it is readily reconvertible into urea by the usual processes.

6. Chlorine, when transmitted into an aqueous solution of urea, resolves the latter into carbonic acid and nitrogen, whilst hydrochloric acid is formed:

$$ZH^4,CNO + HHO + 6Cl = CO^2 + 2N + 6HCl.$$

In this case the nitrogen is set free, in accordance with the observation that was made at page 219, that ammoniums are only produced when there are present, not only sufficient basic radicals to constitute the ammonium, but also negative radicals with which the ammoniums can instantly combine. It is true that water is present in this case, and might be supposed able to supply the requisite hydrogen, but there is no means of escape provided for the oxygen.

7. According to Wurtz, dry chlorine gas, passed through melted

urea, forms cyanuric acid, sal-ammoniac, hydrochloric acid, and nitrogen. This decomposition may be represented in an equation, thus:

$$\left.\begin{matrix}2(ZH^4,CyO)\\ 3Cl\end{matrix}\right\} = \left\{\begin{matrix}2(H,Cy\cdot lO) + ZH^4Cl.\\ 2(HCl\qquad) + N.\end{matrix}\right.$$

8. Urea boiled with excess of oil of vitriol is completely resolved into carbonic acid gas and sulphate of ammonia (*Dumas*):

$$\left.\begin{matrix}ZH^4,CNO\\ 2(HSO^2) + HHO\end{matrix}\right\} = \left\{\begin{matrix}2(ZH^4,SO^2)\\ CO^2.\end{matrix}\right.$$

The cyanate of potash suffers decomposition in a similar manner. See Reaction 4, page 220. This comparative experiment proves that the C and N of the cyanates *can* be separated from one another by an acid, under production of carbonic acid gas.

9. According to Millon, one atom of urea decomposed by two atoms of nitrous acid, produces carbonic acid, nitrogen, and water:

$$\left.\begin{matrix}ZH^4,CNO\\ H,NO^2\\ H,NO^2\end{matrix}\right\} = \left\{\begin{matrix}CO^2\\ 4N\\ 3HHO\end{matrix}\right.$$

10. According to Williamson, when oxamide is heated with oxide of mercury, the products are mercury, carbonic acid, and urea:

$$2\underbrace{(ZH^2,CO)}_{\text{Oxamide.}} + HgcHgcO = HgcHgc + CO^2 + \underbrace{ZH^4,CNO.}_{\text{Urea.}}$$

11. Oxamide, passed in the state of vapour through a glass tube heated to redness, yields, among other products, a large quantity of urea:

$$\underbrace{ZH^2,CO + ZH^2,CO}_{\text{Oxamide, 2 atoms.}} = \underbrace{ZH^4,CNO}_{\text{Urea.}} + \underbrace{CO.}_{\text{Carbonic oxide.}}$$

12. When carbonic ether is heated in a sealed tube, with an alcoholic solution of ammonia, the excess of ammonia slowly converts the carbonic ether into alcohol and urea. *Natanson.*

$$\left.\begin{matrix}\text{Carbonic ether} = C^2H^5,C^2H^5;\ CO^3\\ \text{Ammonia in} \quad ZH^4;\ C^2H^5O\\ \text{alcohol} \quad ZH^4;\ C^2H^5O\end{matrix}\right\} = \left\{\begin{matrix}ZH^4,CNO = \text{Urea.}\\ (H,C^2H^5O)^4 = \text{Alcohol.}\end{matrix}\right.$$

Summary of the Evidence.—The question to be answered is, ought urea to be considered as carbamide = ZH^2,ZH^2,CO, or as cyanate of ammonia = ZH^4,CNO? It is needless to ask if it corresponds to the clump formula CH^4N^2O, because that formula is confessedly a declaration of ignorance of any form of proximate constitution. The decision, then, lies between carbamide and cyanate of ammonia, and that decision depends in a great measure upon considerations which I have fully discussed in other parts of this work, and to which I have already asked the reader to refer.

The main argument urged in favour of the carbamide theory, is, that urea readily produces carbonic acid and ammonia when it is heated with hydrated alkalies and strong acids. But that argument was certainly not based upon a full consideration of the character of the azotic radicals, and of the transmigrations which azote undergoes under the pressure of different chemical forces. These transmigrations I have traced in great detail, and I may say that it is demonstrated, that a cyanate can give off carbonic acid as readily as if it contained carbonic oxide or even carbonic acid ready formed, provided you supply the radicals that are necessary to occupy the azote which the cyanate liberates when it gives off the carbonic acid. It is simply a question of the balance of the powers which are brought into simultaneous operation.

Then, in regard to the disengagement of ammonia, we find that a *cold* solution of an alkali does not liberate it, but that a *hot* solution liberates it, and that fusion of the mixed salts in the dry state liberates it. A corresponding action has been described in the treatment of isatine with caustic potash. See page 261. In that case a cold solution of KHO has this reaction: $ZH^2 + KHO = ZHK + HHO$; while a hot solution has this reaction: $ZH^2 + KHO = ZH^3KO$. Applying this illustration to urea, we may imagine that the mixture $ZH^4,CyO + KHO$ (*cold*) produces $ZH^3K,CyO + HHO$, in which case no ammonia is expelled; but that when KHO (*hot*) is applied, the reaction becomes $ZH^4,CyO + KHO = KCyO + ZH^4,HO (= ZH^2,H + H,HO)$, which, of course, disengages ammonia. In the presence of an excess of potash, the reaction does not end here, but, as is shown by reaction 3, the cyanogen is next decomposed, and the final results of the decomposition of the urea are ammonia and carbonate of potash.

To enter farther into details would be only to repeat what I have said in the sections to which I have made reference. Briefly, I may conclude, that every one of the reactions of urea agrees with the theory, that its true constitution is that of cyanate of ammonia $= ZH^4,CyO$. The notion that it is carbamide $= ZH^2,ZH^2,CO$, is discordant with the whole series of facts that have been disclosed in the course of this investigation of the theory of the azotic radicals.

Examples of Ureas.

NORMAL UREA.

1.	$ZH^4 ; CyO$	Ammona cyanate.

COMPOUND UREAS. *Group* A.

2.	$ZH^3,CH^3 ; CyO$	Methylam cyanate.
3.	$ZH^3,C^2H^5 ; CyO$	Ethylam cyanate.
4.	$ZH^3,C^3H^5 ; CyO$	Allylam cyanate.
5.	$ZH^3,C^5H^{11} ; CyO$	Amylam cyanate.
6.	$ZH^3,C^6H^5 ; CyO$	Phenylam cyanate.
7.	$ZH^3,C^7H^7 ; CyO$	Toluenylam cyanate.
8.	$ZH^3,C^{10}H^7 ; CyO$	Naphtylam cyanate.

COMPOUND UREAS. *Group* B.

9.	$ZH^2(C\,H^3)^2 ; CyO$	Methylem cyanate.
10.	$ZH^2(C^2H^5)^2 ; CyO$	Ethylem cyanate.
11.	$ZH^2(C^5H^{11})^2 ; CyO$	Amylem cyanate.
12.	$ZH^2(C^3H^5)^2 ; CyO$	Allylem cyanate.
13.	$ZH^2(C^6H^5)^2 ; CyO$	Phenylem cyanate.
14.	$ZH^2(C^{10}H^7)^2 ; CyO$	Naphtylem cyanate.

COMPOUND UREAS. *Group* C.

15.	$ZH^2,C\,H^3,C^2H^5 ; CyO$	Methylic-ethylam cyanate.
16.	$ZH^2,C^2H^5,C^5H^{11} ; CyO$	Ethylic-amylam cyanate.
17.	$ZH^2,C^2H^5,C^6H^5 ; CyO$	Ethylic-phenylam cyanate.

COMPOUND UREAS. *Group* D.

18.	$Z(C^2H^5)^4 ; CyO$	Ethylom cyanate.

SALTS OF UREA.

19.	$ZH^4,CyO + HNO^3$	Ammona cyanate cum hydra nitrite.
20.	$ZH^4,CyO + AgNO^3$	Ammona cyanate cum argenta nitrite.
21.	$ZH^4,CyO + 2AgNO^3$	Ammona cyanate bis argenta nitrite.
22.	$ZH^4,CyO + HCO^2$	Ammona cyanate cum hydra carbete.

23.	$ZH^4,CyO + HCyO$ . . .	Ammona cyanate cum hydra cyanate.
24.	$ZH^4,CyO + NaCl$ . . .	Ammona cyanate cum natra chlora.
25.	$H,CyO + HCl$ . . .	Hydra cyanate cum hydra chlora.
26.	$ZH^3,CH^3; CyO + HNO^3$.	Methylam cyanate cum hydra nitrite.
27.	$ZH^3,C^6H^5; CyO + AgNO^3$	Phenylam cyanate cum argenta nitrite.

THEORY OF COMPOUND UREAS.

The Compound Ureas differ from Normal Urea precisely to the same extent that all the salts of vice-ammoniums differ from the corresponding salts of normal ammonium, namely, by the replacement of H^1, H^2, H^3, or H^4 of the ammonium by an equal number of equivalents of compound radicals. The compound ureas are, therefore, in all probability, constructed in the same manner as normal urea, so that if the latter is to be considered as a cyanate of ammonium, the former must be considered as cyanates of vice-ammoniums. If it were in accordance with discovered facts to consider normal urea as carbamide, it would be equally in accordance with facts to represent the compound ureas as compound carbamides. This representation is, in fact, made by many chemists, and I have quoted, between pages 298 and 301, the arguments by means of which one of the most distinguished investigators of organic bases has endeavoured to fix the character of carbamides upon the two salts that are numbered 6 and 13 in the above Table. I have examined the bearings of his arguments, and pointed out their weakness, and I have drawn from that examination the conclusion, that the doctrine of carbamides is invalid, and that the chemical reactions of the two compounds in question, demonstrate that they are undoubtedly cyanates of vice-ammoniums. Dr. Hofmann, as I have shown, decides in favour of the carbamide theory. Gerhardt admits that "as it is possible to represent ordinary urea as a cyanate of ammonia, it is evident that compound ureas can be equally expressed by similar rational formulæ;" but he decides in favour of the "type ammonia," and gives to the ureas a series of formulæ of which the following are examples:—

$$\left.\begin{array}{l}\text{Methyl-urea . . }\\\text{No. 2 in the Table}\end{array}\right\} = C^2H^6N^2O = N^2\left\{\begin{array}{l}CO\\CH^3\\H^3\end{array}\right.$$

$$\left.\begin{array}{l}\text{Ethylamyl-urea . }\\\text{No. 16 in the Table}\end{array}\right\} = C^8H^{18}N^2O = N^2\left\{\begin{array}{l}CO\\C^2H^5\\C^5H^{11}\\H^2\end{array}\right.$$

In these formulæ $C = 12$, $O = 16$, and the symbol CO signifies an oxidised radical, which Gerhardt calls *carbonyle*, and which he considers to be the equivalent of H^2. These formulæ represent, therefore, a double atom of ammonia, and neither a cyanate nor a carbamide. It is needless to discuss this proposal, because I have explained, at page 233, the philosophy, or rather the phantasy, of the ammonia type.

USUAL NAMES, FORMULÆ, DERIVATIONS, &C., OF THE COMPOUND UREAS.—It would be a waste of time to go over the compound ureas, one by one, and recite at length and examine critically the names, formulæ, and theories, that have been attached by different chemists to each of them. A glance at the Table from No. 2 to No. 18, shows the relative compositions of these salts, and how completely they all agree with the two propositions, that they are *cyanates*, and that they contain *vice-ammoniums*. In Group A, we have ammonams; in Groups B and C we have ammonems; in Group D an ammonom. I shall quote a few of the common names and formulæ, in order to identify the compounds, and refer to some of their modes of derivation and their characteristic reactions; but I assume, once for all, that I am speaking of cyanates of vice-ammoniums, and I shall only quote other formulæ to explain the views of other chemists.

GROUP A. NOS. 2 to 8. *Cyanates of Ammonams.*

2. Methyl-urea = $H^3(C^2H^3)N^2C^2O^2$, *Miller*.

He describes it as being derived from methyl-cyanic ether (see No. 431, page 250,) and ammonia, thus: $C^2H^3O,C^2NO + H^3N$, and as being a urea in which the place of one equivalent of hydrogen has been supplied by one equivalent of the radical of the ether. Thus:—

$$\text{Ordinary urea} = H^3(\quad H)N^2C^2O^2 \left\{\begin{array}{l}\text{From hydrated cyanic acid}\\ \quad\text{and ammonia.}\end{array}\right.$$

$$\text{Methyl-urea} \quad = H^3(C^2H^3)N^2C^2O^2 \left\{\begin{array}{l}\text{From methylcyanic ether}\\ \quad\text{and ammonia.}\end{array}\right.$$

It is evident, that this is a reaction, in which the cyanate of a compound hydrocarbon is converted into the cyanate of an ammonam, by the assumption of ammonia, thus:

$$ZH^2H + CH^3,CyO = ZH^3,CH^3;\ CyO.$$

Gmelin gives the following formulæ for methyl-urea:

$$C^4H^6N^2O^2 = C^2H^2,C^2H^4N^2O^2 = C^2\left\{\begin{matrix}H^3\\ C^2H^3\end{matrix}\right\}N^2O^2.$$

Gerhardt's formulæ on the ammonia type I have quoted above from vol. 4 of his *Traité*. In vol. 1 he gives these two formulæ:

$$C^4H^6N^2O^2 = \left.\begin{matrix} NCyH^3.O \\ C^2\,H^3.O \end{matrix}\right\}, \text{ in which } C = 6, O = 8.$$

The last of these formulæ is formed on the model of water, in which one of the atoms of hydrogen is assumed to be replaced by methyl, and the other by the very strange compound $NCyH^3$, which he calls *cyanammonium*, a thing which exists only in symbols.

The examples Nos. 3 to 8 I may pass over without further notice, as their usual names and formulæ would be parallel to those of methyl-urea, and exhibit the same crudeness. No. 6 is described at page 298.

Group B. Nos. 9 to 14. *Cyanates of Ammonems.*

When the cyanates of basic radicals are placed in contact with water, they evolve carbonic acid and produce cyanates of ammonems. Thus:

$$\left.\begin{matrix} \text{Methyla cyanate} \\ \text{No. 431, p. 250} \end{matrix}\right\} = \left\{\begin{matrix} CH^3,CNO \\ CH^3,CNO \\ H,HO \end{matrix}\right\} = \left\{\begin{matrix} ZH^2,CH^3,CH^3;\ CNO = \text{No. 9.} \\ CO^2 \\ \ \end{matrix}\right.$$

The salts Nos. 10, 11, and 12, are produced in the same way. No. 13 has been fully discussed as No. 90 of the aniline series. No. 14 is produced by the action of heat on the oxalate of naphtylamine ($= ZH^2,C^{10}H^7;\ CO^2$ = naphtylam carbete). *Usual names*: No. 9, Dimethyl-urea. No. 10, Diethyl-urea. No. 11, Diamyl-urea. No. 12, Diallyl-urea; diacryl-urea; sinapoline. No. 13, Diphenyl-urea; flavine; and carbanilide. No. 14, Dinaphtyl-carbamide, or naphtalidamic carbamide. I will notice the usual formulæ for one salt only, No. 13. Hofmann's formula I have quoted at page 300:—

$$\text{Gerhardt's (vol. 1)} = C^{26}H^{12}N^2O^2 = \left.\begin{matrix} NCyH^2(C^{12}H^5).O \\ C^{12}H^5\ .O \end{matrix}\right\}$$

$$\text{Gerhardt's (vol. 4)} = C^{13}H^{12}N^2O = N^2\left\{\begin{matrix} CO \\ (C^6H^5)^2 \\ H^2 \end{matrix}\right.$$

$$\text{Miller's} = C^{26}H^{12}N^2O^2 = \left.\begin{matrix} C^2O^2 \\ 2(C^{12}H^5) \\ H^2 \end{matrix}\right\}N^2.$$

From these specimens it will be seen that while Hofmann advocates the carbamide theory, Gerhardt first proposes the model of water, and then the ammonia type, and that in the last form he is followed by Miller.

Group C. Nos. 15 to 17. *Cyanates of Ammonems.*

These salts differ from those in Group B merely by containing two different compound radicals instead of two equivalents of the same compound radical. Usual formulæ for Ethyl-methyl-urea, No. 15:—

$$\text{Gerhardt's (vol. 1)} = C^8H^{10}N^2O^2 = \left.\begin{array}{r}NCyH^2(C^2H^3).O\\ C^4H^5.O\end{array}\right\}$$

$$\text{Gerhardt's (vol. 4.)} = C^4H^{10}N^2O = N^2\left\{\begin{array}{l}CO\\ CH^3\\ C^2H^5\\ H^2\end{array}\right.$$

$$\text{Miller's} = C^8H^{10}N^2O^2 = \left.\begin{array}{r}C^2O^2\\ C^4H^5\\ C^2H^3\\ H^2\end{array}\right\}N^2 = \left.\begin{array}{l}C^6H^9N,\\ HO,CyO\end{array}\right\}$$

Here, restricting ourselves to two authors, we have, first, the clump formula, that innocent thing which resembles a direction-post with the inscription rubbed out, and which does not send us astray only because it does not tell us to go anywhere; secondly, we have the model of water; thirdly, the ammonia type; to both of which I have given elsewhere their proper modicum of praise; and fourthly, we have a binary formula, which assumes the salt to consist of hydrated cyanic acid, in combination with the ammonia called methyl-ethylamine (= methylac ethyla, No. 27, page 200). The objection which I have to make to this last formula is, that it represents an extreme improbability; for the amidogen salt $ZH,CH^3;\ C^2H^5$, put in contact with the hydrated acid H,CyO, would produce the ammonium salt $ZH^2,CH^3,C^2H^5;\ CyO$. We cannot admit that the non-permanent cyanate of ammonia is rapidly converted into the permanent cyanate of ammonium, and at the same time insist that the permanent compound cyanates or ureas assume and retain the form that belongs to the fugitive cyanates.

GROUP D. No. 18. $Z(C^2H^5)^4,CyO$. *Ethylom cyanate.*

Miller's name for this salt is Tetrethyl-urea, and his formulæ are:

$$C^{18}H^{20}N^2O^2 = \left.\begin{array}{r}C^2O^2\\ 2(C^4H^5)\\ 2(C^4H^5)\end{array}\right\}N^2 = \left.\begin{array}{c}C^{16}H^{20}N,O\\ CyO\end{array}\right\}.$$

$$\text{Gerhardt, vol. 1} = NCy\left.\begin{array}{r}(C^4H^5)^3.O\\ C^4H^5\ \ .O\end{array}\right\}. \quad \text{Vol. 4} = N^2\left\{\begin{array}{c}CO\\ (C^2H^5)^4.\end{array}\right.$$

SALTS OF UREA. Nos. 19 to 27.

Normal urea and the compound ureas combine with hydrated acids and with neutral salts, to form double salts, such as are represented in the Table of examples, Nos. 19 to 27. All the compounds formed with hydrated acids, retain their acid reactions. There is, of course, no neutralisation of the saturating capacities of the acids effected by the ureas, which have been inconsiderately and improperly termed "bases." They combine with acids, not in the sense in which anhydrous potash is assumed to combine with anhydrous sulphuric acid, effecting the neutralisation of its acidity; but in the sense in which neutral sulphate of potash combines with hydrated sulphuric acid, producing a double salt, but not affecting the saturating capacity of the hydrated acid. The application of the term "base" to a neutral salt when acting in this manner has produced much of the ambiguity which pervades most chemical writings on the subject of the salts which contain hydrogen.

It is needless to enter into details respecting these compounds individually. Their composition is evident from the symbols, and I only insist upon the broad fact, that these are double salts, and that to regard them as compounds of acids with a base is improper. Urea is never, under any circumstances, a "base."

Terbasic Cyanates.

In describing Dr. Hofmann's Anilocyanates, I have suggested (see page 305) that these salts may have the constitution of Terbasic Cyanates, or be produced by the combination of a monobasic cyanate with a salt formed on the model of water, $H,CH^3O + C^6H^5,CyO = H,CH^3,C^6H^5; CyO^2$. See Aniline, No. 96, and No. 3 in the following Table. There are many other salts that have similar proportions of ultimate constituents, and which are liable to a similar interpretation; while the processes by which some of them are prepared, and the products of their decomposition, give strength to this hypothesis. Nevertheless, many of the facts upon which we must build the theory of terbasic cyanates are liable to so many other interpretations, that I can only state the hypothesis in a general form as one for *consideration*, and not as one that is *established*. Certainly, the arguments which I have adduced at pages 305 and 306 are strongly in favour of the supposition that the anilocyanates are terbasic cyanates; but the evidence respecting some other of the compounds in the following Table is neither so direct nor so conclusive as that respecting the anilocyanates, though, as it appears to me, it is sufficiently affirmative to warrant my grouping the compounds into a class for future investigation.

We cannot produce terbasic cyanic acid, because, as I have pointed out at page 338, when hydrated cyanic acid $= H,CNO$ acts upon water $= HHO$, they are resolved into ammonia ZH^2H and carbonic acid $= CO^2$. But this reaction is no disproof of the existence of terbasic cyanates, containing other basic radicals than H,H,H; because we have examples of the production of some of these salts by the direct action of hydrated cyanic acid upon hydrated oxides formed on the model of water, as will be seen in the following descriptions:—

Examples of Terbasic Cyanates.

1.	H, H, C^6H^5 ; CyO^2 .	Hydra hydra phenyla cyanete.
2.	H, C^6H^5, C^6H^5 ; CyO^2 .	Hydra phenyla phenyla cyanete.
3.	H, CH^3, C^6H^5 ; CyO^2 .	Hydra methyla phenyla cyanete.
4.	H, C^2H^5, C^6H^5 ; CyO^2 .	Hydra ethyla phenyla cyanete.
5.	H, C^5H^{11},C^6H^5 ; CyO^2 .	Hydra amyla phenyla cyanete.
6.	H, K, C^6H^5 ; CyO^2 .	Hydra potassa phenyla cyanete.
7.	H, Na, C^6H^5 ; CyO^2 .	Hydra natra phenyla cyanete.
8.	H, Ba, C^6H^5 ; CyO^2 .	Hydra baryta phenyla cyanete.
9.	H, Sr, C^6H^5 ; CyO^2 .	Hydra stronta phenyla cyanete.
10.	H, Ca, C^6H^5 ; CyO^2 .	Hydra calca phenyla cyanete.
11.	H, Mg, C^6H^5 ; CyO^2 .	Hydra magna phenyla cyanete.
12.	H, Ag, C^6H^5 ; CyO^2 .	Hydra argenta phenyla cyanete.
13.	H, Cuc, C^6H^5 ; CyO^2 .	Hydra cupric phenyla cyanete.
14.	H, H, CH^3 ; CyO^2 .	Hydra hydra methyla cyanete.
15.	H, Ag, CH^3 ; CyO^2 .	Hydra argenta methyla cyanete.
16.	H, Zn, CH^3 ; CyO^2 .	Hydra zinca methyla cyanete.
17.	H, H, C^2H^5 ; CyO^2 .	Hydra hydra ethyla cyanete.
18.	H, C^2H^5, C^2H^5 ; CyO^2 .	Hydra ethyla ethyla cyanete.
19.	H, H, C^5H^{11}; CyO^2 .	Hydra hydra amyla cyanete.
20.	H, H, C^4H^9 ; CyO^2 .	Hydra hydra butyla cyanete.
21.	H, H, C^7H^7 ; CyO^2 .	Hydra hydra toluenyla cyanete.
22.	H, H, C^9H^{11}; CyO^2 .	Hydra hydra cumenyla cyanete.
23.	CH^3, CH^3, ZH^4 ; CyO^2 .	Methyla methyla ammona cyanete.
24.	C^2H^5,C^2H^5, ZH^4 ; CyO^2 .	Ethyla ethyla ammona cyanete.
25.	Hgc, Hgc, ZH^4 ; CyO^2 .	Meric meric ammona cyanete.
26.	H, H, ZH^4 ; CyO^2 .	Hydra hydra ammona cyanete.

USUAL NAMES AND FORMULÆ OF THE TERBASIC CYANATES.

1]. H,H,C^6H^5; CyO^2. Hydren phenyla cyanete. Anthranilic acid; benzamic acid; carbanilidic acid = $C^{14}H^7NO^4$ = HO . CO^2; $C^{12}H^6N$, CO = HO . C(O,$C^{12}H^6N$)CO^2, *Hofmann*, who adds, that he considers these three acids to be identic. Phenyl-carbamic, carbanilic, or

anthranilic acid = $C^{14}H^7NO^4$ = $\left.\begin{matrix} NH(C^{12}H^5)(CO)^2O \\ HO \end{matrix}\right\}$ *Gerhardt.*

Anthranilic acid (HO,$C^{14}H^6NO^3$), *Miller*. Benzamic; carbanilic, or amido-benzoic acid = $C^{14}H^7NO^4$ = HO,$C^{14}H^4$,H^2N,O^3, *Miller*. A great many other formulæ have been applied to those substances, the proximate composition of which is not understood, nor is it yet even decidedly ascertained whether there is one, or two, or three compounds of different properties having the same ultimate composition $= C^7H^7NO^2$.

While suggesting that the compound No. 1 may be a terbasic cyanate, in agreement with the formula $H,HO + C^6H^5,CyO$, it is proper to place before the reader some of the other formulæ, according to which the ultimate composition may be interpreted.

a). $C^6H^5; ZH^2; CO^2$. This represents an amide derived from a neutral carbonate, having one equivalent of ammonium and one of phenyl, thus:

$$C^6H^5; ZH^4; CO^3 - HHO = C^6H^5; ZH^2; CO^2.$$

By some chemists the formula *a*) would be understood to signify the carbamate of phenyl.

b). $ZH,C^6H^5; H; CO^2$. This represents an anilidogen acid derived from the bicarbonate of phenylam by abstraction of HHO:

$$ZH^3,C^6H^5; H; CO^3 - HHO = ZH,C^6H^5; H; CO^2.$$

c). $ZH^2,C^7H^5O^2$. In this case all the carbon of the compound is placed together so as to increase the acid energy of the negative radical, and the nitrogen then forms an amid with the two basic radicals. Most of the salts in the table are liable to this treatment, but it happens in regard to many of them that the true amids having the same ultimate composition are otherwise known, and have properties that differ from those of the substances that are referred to in this Table.

The formulæ which I have quoted from Miller, Hofmann, and Gerhardt, represent acid radicals, which include carbon in combination with amidogen or phenylac. It is needless to resort to the expedient of framing imaginary conjugated radicals, while we have before us several more probable and more simple methods, by means of which the transformations of the compounds can be sufficiently explained. Of these several formulæ I prefer that which regards the compounds as being terbasic cyanates; but we have not sufficient knowledge of facts to be able to decide exclusively in favour of this or of any one formula.

Anthranilic acid, when heated, produces aniline and carbonic acid gas:

$$H,H,C^6H^5; CNO^2 = ZH,C^6H^5; H + CO^2.$$

The formulæ marked *a*), *b*), *c*), suit this experiment equally well, so that the experiment proves nothing beyond the accuracy of the clump formula $C^7H^7NO^2$. Benzamic acid is said not to produce aniline when heated.

2]. $H,C^6H^5,C^6H^5; CyO^2$. Hydra phenylen cyanete. A combination of anilocyanic acid with hydrated oxide of phenyl. *Hofmann.* Thus:

$$C^6H^5,CyO + H,C^6H^5O = H,C^6H^5,C^6H^5; CyO^2.$$

3]. $H,CH^3,C^6H^5; CyO^2$. Hydra methyla phenyla cyanete. See

Aniline 96]. A compound of the same composition, discovered by Chancel, is called by Gerhardt the phenyl-carbamate of methyl, or carbanimethylane.

4]. $H,C^2H^5,C^6H^5;\ CyO^2$. Hydra ethyla phenyla cyanete. See Aniline 97]. Also Chancel's compound, called by Gerhardt phenyl-carbamate of ethyl, or carbanilethane. This last compound is converted by ammonia into alcohol and anilo-urea (Aniline 89):

$$\left.\begin{array}{l} H,C^2H^5,C^6H^5;\ CyO^2 \\ ZH^2H \end{array}\right\} = \left\{\begin{array}{r} ZH^2,C^6H^5;\ CyO = \text{Anilo-urea.} \\ H,C^2H^5O = \text{Alcohol.} \end{array}\right.$$

5]. $H,C^5H^{11},C^6H^5;\ CyO^2$. Hydra amyla phenyla cyanete. See Aniline 98].

6]. $H,K,C^6H^5;\ CyO^2$. Hydra potassa phenyla cyanete. Benzamate of potash. Phenyl-carbamate of potash. Scarcely known.

7]. $H,Na,C^6H^5;\ CyO^2$. Hydra natra phenyla cyanete. Amido-benzoate (Benzamate) of soda = $C^{14}H^4Na(NH^2)O^4$, *Voit. Quart. Journ. Chem. Soc.*, ix. 269.

8, 9, 10, 11]. Amido-benzoates or benzamates of barytes, strontia, lime, and magnesia; described by Voit, (*loc. cit.*) There is also a phenyl-carbamate of lime. *Chancel.*

12]. $H,Ag,C^6H^5;\ CyO^2$. Hydra argenta phenyla cyanete. Carbanilate of silver; anthranilate of silver; benzamate of silver.

13]. $H,Cuc,C^6H^5;\ CyO^2$. Hydra cupric phenyla cyanete. Benzamate of copper; carbanilate of copper.

14]. $H,H,CH^3;\ CyO^2$. Hydren methyla cyanete. Two compounds answer to this formula, both of which have undergone, and still undergo, much discussion. Whether or not either of them belongs to this category has yet to be finally determined. They are named urethylane, (carbamate of methyl or carbomethylane) and glycocoll.

Urethylane is formed by saturating wood-spirit with the vapour of cyanic acid. This reaction gives us $H,CH^3O + HCyO$, which is precisely the composition of a terbasic cyanate. It is also produced by passing gaseous chloride of cyanogen into wood-spirit mixed with water, which is also in accordance with this idea:

$$H,CH^3O + HHO + CyCl = H,H,CH^3;\ CyO^2 + HCl.$$

It suffers the following decompositions:

$$\text{1]. }\left.\begin{array}{lr} & H,H,CH^3;\ CNO^2 \\ \text{Sulphuric acid} & H;\ \ SO^4 \\ \text{Water} & H;\ \ HO \end{array}\right\} = \left\{\begin{array}{rl} ZH^4,SO^4 & \text{Sulphate of ammonia.} \\ H,CH^3O & \text{Wood spirit.} \\ CO^2 & \text{Carbonic acid.} \end{array}\right.$$

$$\text{2.] }\left.\begin{array}{lr} & H,H,CH^3;\ CNO^2 \\ \text{Caustic potash} & \left\{\begin{array}{l} K;\ HO \\ K;\ HO \end{array}\right. \end{array}\right\} = \left\{\begin{array}{rl} KK,CO^3 & \text{Carbonate of potash.} \\ H,CH^3O & \text{Wood spirit.} \\ ZH^2,H & \text{Ammonia.} \end{array}\right.$$

These reactions are precisely such as arise from the decomposition of a compound that contains cyanogen, and agree perfectly with Formula 14].

Urethylane is also called carbamate of methyl, and is assumed to contain the hypothetical carbamic acid. See page 359.

Glycocoll, or sugar of gelatine, is obtained by the action of alkalies and acids upon gelatine. It combines with acids without neutralising them; its solution reddens litmus feebly; these are characters which agree very well with the above formula. It can exchange H^1 for a metal, especially for Zn, Cuc, Pb, Ba, and Ag. Nos. 15 and 16 in the Table are examples of such salts. They can be formed by heating the hydrated oxides of the metals with a solution of glycocoll:

$$\left.\begin{array}{r} H,H,CH^3 ; CyO^2 \\ Ba ; HO \end{array}\right\} = \left\{\begin{array}{r} H,Ba,CH^3 ; CyO^2 \\ H ; HO. \end{array}\right.$$

When glycocoll is boiled with acetate of copper, acetic acid is expelled, and a compound of glycocoll with oxide of copper is obtained in solution:

$$\left.\begin{array}{r} H,H,CH^3 ; CyO^2 \\ Cuc ; C^2H^3O^2 \end{array}\right\} = \left\{\begin{array}{r} H,Cuc,CH^3 ; CyO^2 \\ H ; C^2H^3O^2. \end{array}\right.$$

15] and 16]. Salts of glycocoll. See last note.

17]. $H,H,C^2H^5 ; CyO^2$. Hydren ethyla cyanete. The clump formulæ of several known compounds agree with this formula. The most important of these are urethane (or carbamate of ethyl), sarkosine, alanine, and lactamide. But if there exist several acid radicals having the formula C^2H^5, respecting which I have made some inquiries in the section on glycerin, it is probable that there are several amides isomeric with lactamide. The compounds that are here referred to, though alike in ultimate composition, differ from one another in certain properties, but have not had their characters fully determined. It is therefore impossible to say how many of them, if any, ought to be embraced in the category of terbasic cyanates. I do not enter into details, because I find among them no facts that point out conclusive arguments respecting the proximate composition of these several salts.

18]. $H,C^2H^5,C^2H^5 ; CyO^2$. Hydra ethylen cyanete. Ethylurethane, or ethyl-carbamate of ethyle = $C^{10}H^{11}NO^4 = C^6H^6(C^4H^5)NO^4$, *Gerhardt*. Produced by heating cyanate of ethyl with alcohol in a closed glass tube, thus:

$$H,C^2H^5O + C^2H^5,CyO = H,C^2H^5,C^2H^5 ; CyO^2.$$

It is decomposed by caustic potash, which produces alcohol, ethylamine, and carbonate of potash, thus:

$$\left.\begin{array}{r} H,C^2H^5O + C^2H^5,CNO \\ KHO \\ KHO \end{array}\right\} = \left\{\begin{array}{ll} H,C^2H^5O & \text{Alcohol.} \\ ZH,C^2H^5 ; H & \text{Ethylamine.} \\ KK,CO^3 & \text{Carbonate of potash.} \end{array}\right.$$

When heated with concentrated sulphuric acid, it produces carbonic acid, sulphate of ethylamine and sulphovinic acid:

$$\left.\begin{array}{r} H,C^2H^5,C^2H^5,CNO^2 \\ H,SO^2 \\ H,SO^2 \\ H,SO^2 \end{array}\right\} = \left\{\begin{array}{l} ZH^3,C^2H^5;\ SO^2 \quad \text{Sulphate of ethylamine.} \\ \left\{\begin{array}{r} C^2H^5;\ SO^2 \\ H\ ;\ SO^2 \end{array}\right\} \text{Sulphovinic acid.} \\ \qquad\quad CO^2 \end{array}\right.$$

These reactions all agree with the theory that ethylurethane is a terbasic cyanate, containing two atoms of ethyl.

19]. $H,H,C^5H^{11};\ CyO^2$. Hydren amyla cyanete. Amylo-urethane, or carbamate of amyle, discovered by Mr. Medlock (*Quart. Jour. of the Chem. Soc.*, ii. 212). Formulæ:

$$= C^{12}H^{13}NO^4 = C^{10}H^{13}N + 2CO^2 = C^{10}H^{11}O,C^2\left\{\begin{array}{c} O^3 \\ NH^2 \end{array}\right\}.$$

This salt was produced by the action of ammonia on the chloro-carbonate (*i. e.* the chloric-formylete) of amyle, thus:

$$\left.\begin{array}{r} C^5H^{11},CClO^2 \\ ZH^2H + ZH^2H \end{array}\right\} = \left\{\begin{array}{r} H,H,C^5H^{11};\ CNO^2. \\ ZH^4,Cl. \end{array}\right.$$

When this salt is distilled with caustic baryta, it produces ammonia, carbonic acid, and hydrated oxide of amyle:

$$\left.\begin{array}{r} H,H,C^5H^{11};\ CNO^2 \\ BaHO \\ BaHO \end{array}\right\} = \left\{\begin{array}{l} ZH^2H \\ BaBa,CO^3. \\ H,C^5H^{11}O \end{array}\right.$$

When heated with sulphuric acid, it produces sulphamylic acid and ammonia, with evolution of carbonic acid (and sulphurous acid?):

$$\left.\begin{array}{r} H,H,C^5H^{11};\ CNO^2 \\ HSO^2 \\ HSO^2 \end{array}\right\} = \left\{\begin{array}{l} \left.\begin{array}{r} C^5H^{11},SO^2 \\ H,SO^2 \end{array}\right\} \text{Sulphamylic acid.} \\ ZH^2H + CO^2. \end{array}\right.$$

The sulphurous acid must have proceeded from a subsequent decomposition of part of the sulphamylic acid.

These reactions show that amylo-urethane agrees perfectly with the character of a terbasic cyanate.

Another compound which corresponds to the same formula as amylo-urethane is leucine; but though its reactions do not indicate so clearly as those of amylo-urethane that its composition is that of a terbasic cyanate, yet there are many points of resemblance. It combines with metals to form salts, of which the following is an example: $H,Pb,C^5H^{11};\ CyO^2$. By dry distillation leucine produces amylamine and carbonic acid, thus:

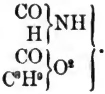
$$H,H,C^5H^{11};\ CNO^2 = ZH,C^5H^{11};\ H + CO^2.$$

20]. $H,H.C^4H^9;\ CyO^2$. Hydren butyla cyanete. Carbamate of tetryle;

butylic urethane; tetrylic urethane = $C^{10}H^{11}NO^{4}$, *Gerhardt*. It is produced, according to Humann, by acting on butylic alcohol with liquid chloride of cyanogen:

$$\left.\begin{array}{r} 4(H,C^{4}H^{9}O) \\ 2(CNCl) \\ HHO \end{array}\right\} = \left\{\begin{array}{rcl} C^{4}H^{9},C^{4}H^{9};\ CO^{3} & = & \text{Carbonate of butyl.} \\ H,H,C^{4}H^{9};\ CNO^{2} & = & \text{No. 20].} \\ C^{4}H^{9};\ Cl & = & \text{Chloride of butyl.} \\ ZH^{4};\ Cl & = & \text{Sal-ammoniac.} \end{array}\right.$$

According to Humann, the formula is



$$\left.\begin{array}{r} \left.\begin{array}{r} CO \\ H \end{array}\right\}NH \\ \left.\begin{array}{r} CO \\ C^{8}H^{9} \end{array}\right\}O^{2} \end{array}\right\}.$$

This is interpreted in Gmelin's *Handbook* (x. 149) to signify that the salt is a compound of carbonate of butyl with carbamide = $C^{8}H^{9}O,CO^{2} + CNH^{2}O$. The objections to this supposition are, that it includes belief in a compound of the existence of which we have no evidence (carbamide, see page **221**), and that, besides this, the theory is less probable, and the formula more complex, than the theory and corresponding formula now advanced.

21]. $H,H,C^{7}H^{7};\ CyO^{2}$. Hydren toluenyla cyanete. The toluamic acid of Cahours.

22]. $H,H,C^{9}H^{11};\ CyO^{2}$. Hydren cumenyla cyanete. The cuminamic acid of Cahours.

23]. $CH^{3},CH^{3},ZH^{4};\ CyO^{2}$. Methylen ammona cyanete. A combination of methylic ether = $CH^{3},CH^{3}O$ with cyanate of ammonia = ZH^{4},CyO. This is Gmelin's anhydrous carbonate of methylamine = $C^{2}H^{5}N,CO^{2}$. Gerhardt's formulæ are $C^{2}O^{4},2C^{2}H^{5}N$ and $C^{4}H^{4}(HC^{2}H^{5}N)NO^{4}$. He assumes in it the presence of a methyl-carbamic acid = $C^{4}H^{5}NO^{4}$, of the existence of which we have no proof, and for which there is no necessity. The salt, **23**], is produced by the combination of two volumes of carbonic acid = CO^{2} with four volumes of methylamine, see page **61** = $2(ZH,CH^{3};\ H)$, and the product might be formulated thus: $ZH^{3},CH^{3};\ ZH,CH^{3};\ CO^{2}$, in which form it is analogous to the anhydrous carbonate of ammonia. See No. **1**] in the series of carbonates of ammonia on the next page.

24]. $C^{2}H^{5},C^{2}H^{5},ZH^{4};\ CyO^{2}$. Ethylen ammona cyanete. This salt is of similar composition to No. **23**], excepting that it contains methyl instead of ethyl. It is subject to the same diversity of explanations, and gives origin to another hypothetical acid, the ethyl-carbamic acid.

25]. $Hgc,\ Hgc,ZH^{4};\ CyO^{2}$. Merenic ammona cyanete. This salt is formed when successive portions of red oxide of mercury suspended in water are mixed with a warm solution of urea:

$$Hgc,HgcO + ZH^{4},CyO = Hgc,Hgc,ZH^{4};\ CyO^{2}.$$

26]. $H,H,ZH^4; CyO^2$. Hydren ammona cyanete. This salt looks like the "acid" which corresponds to the three preceding salts. Its occurrence is possible: $H,HO + ZH^4,CyO$, namely, an atom of cyanate of ammonia combined with an atom of water; nevertheless, I shall show in the note to No. 1] of the carbonates of ammonia, that this compound has better claims to a different interpretation.

The Carbonates of Ammonia.

1.	ZH^4, ZH^2,CO^2	Ammona amida carbete.
2.	ZH^4, ZH^4,CO^3	Ammona ammona carbite.
3.	ZH^4, ZH^4,CO^3 ZH^4, ZH^2,CO^2	Ammona ammona carbite cum ammona amida carbete.
4.	H, ZH^4,CO^3	Hydra ammona carbite.
5.	H, ZH^4,CO^3 H, ZH^4,CO^3 ZH^4, ZH^2,CO^2	Bis hydra ammona carbite cum ammona amida carbete.
6.	ZH^4, ZH^4,CO^3 ZH^4, ZH^4,CO^3 ZH^4, ZH^4,CO^3 H, ZH^4,CO^3 H, ZH^4,CO^3	Tris ammona ammona carbite bis hydra ammona carbite.
7.	ZH^4, ZH^4,CO^3 ZH^4, ZH^4,CO^3 H, ZH^4,CO^3 H, ZH^4,CO^3 ZH^4, ZH^2,CO^2	Bis ammona ammona carbite bis hydra ammona carbite cum ammona amida carbete.
8.	ZH^4, ZH^4,CO^3 H, ZH^4,CO^3 H, ZH^4,CO^3 $(2HHO)$	Ammona ammona carbite bis hydra ammona carbite cum aquete.
9.	$2(H, ZH^4,CO^3)$ HHO	Hydra ammona carbite demi-aquate.
10.	$4(H, ZH^4,CO^3)$ HHO	Tetrakis hydra ammona carbite cum aquate.
11.	ZH^4, ZH^4,CO^3 $6(H, ZH^4,CO^3)$ $5(HHO)$	Ammona ammona carbite hexakis hydra ammona carbite cum aquute.
12.	$8(H, ZH^4,CO^3$ CO^2 $2(HHO)$	Octakis hydra ammona carbite cum carbete aquete.

[In the above table, $H = 1$, $O = 16$, $C = 12$, $Z = 14$.]

These carbonates of ammonia are all described, after the researches of Heinrich Rose, in Gmelin's *Handbook of Chemistry*, vol. ii. pages 430 to 435. In Gmelin's formulæ, $C = 6$ and $O = 8$. The difference between these atomic weights and those which I have adopted, causes great differences to appear in the formulæ of the salts.

The salt No. **1**] = ZH^4,ZH^2,CO^2 is produced when carbonic acid gas and ammonia gas act upon one another. In whatever proportions they are mixed, they always combine and condense in the proportions of two volumes of carbonic acid = 1 atom CO^2 and four volumes of ammonia = 2 atoms or $ZH^2H + ZH^2H$. This compound is noticed in the Table at p. 50 as the hypothetical carbamate of ammonia. The atomic measure is six volumes, which is the measure of its component gases. Gmelin calls this salt anhydrous mono-carbonate of ammon = NH^3,CO^2. Gerhardt says of this salt, that "the density of its vapour has been found equal to 0·9, *Bineau*, or to 0·8992, *Rose*, and that, consequently, the formula $C^2O^4\,2NH^3$ corresponds to eight volumes, like those of cyanhydrate, sulphhydrate, and chlorhydrate of ammonia," *Traité de Chimie*, i. 196. This is, however, a mistake; the measure is six, not eight, volumes, and it disagrees with the measure of the other gaseous salts of ammonia. See pages 50 and 99.

The salt, No. 1], may be conceived to be formed from the neutral carbonate of ammonia, No. **2**], by the abstraction of an atom of HHO, thus:

$$(ZH^4O + ZH^4O + CO) - HHO = ZH^4O + ZH^2CO.$$

2]. = ZH^4,ZH^4,CO^3. This is the neutral carbonate of ammonia. It is produced when the salt No. 1 is dissolved in water:

$$ZH^4,ZH^2,CO^2 + HHO = ZH^4,ZH^4,CO^3.$$

But it cannot be procured in the solid state. When the aqueous solution is evaporated, ammonia = ZH^2H escapes before the salt crystallises, and a more acid product is left.

3]. $ZH^4,ZH^4,CO^3 + ZH^4,ZH^2,CO^2$. This is Gmelin's hydrated mono-carbonate of ammonia = $2NH^3,HO,2CO^2$, or $NH^3,CO^2 + NH^3,HO,CO^2$. "It is crystalline, it may be sublimed without change in composition; but if it is dissolved in water, it cannot be recovered from the solution; because, even at ordinary temperatures in vacuo, ammonia is disengaged from it, and an acid salt is obtained." *Gmelin*. I consider the solution to contain the salt, No. **2**], because

$$\left.\begin{array}{l} ZH^4,ZH^4,CO^3 \\ ZH^4,ZH^2,CO^2 + HHO \end{array}\right\} = 2(ZH^4,ZH^4,CO^3).$$

4]. H,ZH^4,CO^3. This salt is Gmelin's bicarbonate of ammonia with two atoms of water = $NH^3,HO,CO^2 + HO,CO^2$. A crystalline salt, less soluble and less volatile than the neutral salt No. **2**].

Of course, No. 2 and No. 4 are the two normal carbonates of ammonium. All the other salts in the Table are modifications or combinations of these two.

5]. $2(\mathrm{H,ZH^4,CO^3}) + \mathrm{ZH^4,ZH^2,CO^2}$. A compound of two atoms of the bicarbonate of ammonium No. 4], and one atom of the amidogen salt No. 1]. This is Gmelin's sesquicarbonate of ammonia with two atoms of water $= \mathrm{2NH^3,2HO,3CO^2}$, or according to Rose, $\mathrm{NH^3,CO^2} + \mathrm{NH^3,2CO^2,2HO}$. It is the carbonate of ammonia of commerce. When the vapour of anhydrous sulphuric acid is passed over this salt, carbonic acid gas is disengaged, and ordinary sulphate of ammonia is produced.

$$\left.\begin{array}{r} \left\{\begin{array}{r} \mathrm{H,\ ZH^4,CO^3} \\ \mathrm{H,\ ZH^4,CO^3} \\ \mathrm{ZH^4,ZH^2,CO^2} \end{array}\right. \\ \mathrm{S,SO^3} \\ \mathrm{S,SO^3} \end{array}\right\} = \left\{\begin{array}{r} \left.\begin{array}{l} \mathrm{ZH^4,SO^2} \\ \mathrm{ZH^4,SO^2} \\ \mathrm{ZH^4,SO^2} \\ \mathrm{ZH^4,SO^2} \end{array}\right\} \\ 3(\mathrm{CO^2}) \end{array}\right.$$

"The salt effloresces in the air, forming a friable mass of bicarbonate of ammonia, while anhydrous carbonate of ammon sublimes." *Rose.* Thus:

$$\left.\begin{array}{r} \mathrm{H,\ ZH^4,CO^3} \\ \mathrm{H,\ ZH^4,CO^3} \\ \mathrm{ZH^4,ZH^2,CO^2} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{H,ZH^4,CO^3} \\ \mathrm{H,ZH^4,CO^3} \end{array}\right\} + \mathrm{ZH^4,ZH^2,CO^2}.$$

$$\text{No. 5]} \quad = \text{No. 4]} \quad + \text{No. 1]}.$$

When the sesquicarbonate No. 5] is acted upon with small quantities of water, neutral carbonate of ammonia is first dissolved, and bicarbonate is left undissolved. By the action of successive small doses of water, a series of solutions are obtained which differ in their relative contents of monocarbonate and bicarbonate of ammonia. If, on the other hand, the salt is dissolved in a large quantity of water, and the solution is heated, carbonic acid is disengaged, and the proportion of monocarbonate of ammonia is increased. The instability of these two salts, both in aqueous solution and when exposed to air, gives origin to a great variety of mixtures.

6]. $3(\mathrm{ZH^4,ZH^4,CO^3}) + 2(\mathrm{H,ZH^4,CO^3})$. A compound of three atoms of neutral carbonate of ammonia No. 2] with two atoms of bicarbonate No. 4]. Gmelin's five-fourths carbonate of ammonia with five atoms of water $= \mathrm{4NH^3,5CO^2,5HO}$. Sublimes when the salt No. 5] is slowly heated.

7]. $2(\mathrm{ZH^4,ZH^4,CO^3}) + 2(\mathrm{H,ZH^4,CO^3}) + \mathrm{ZH^4,ZH^2,CO^2}$. Composed of two atoms of No. 2], two atoms of No. 4], and one atom of No. 1]. Gmelin's five-fourths carbonate of ammonia with four atoms of water $= \mathrm{4NH^3,5CO^2,4HO}$, or $2(\mathrm{NH^3,HO,CO^2}) + \mathrm{2NH^3,2HO,3CO^2}$; or, according to H. Rose, $3(\mathrm{NH^3,CO^2}) + \mathrm{NH^4O,2CO^2}$. Produced by the same process as No. 6]. There is, according to Rose, another salt, which contains 12 atoms of water.

8]. $ZH^4,ZH^4,CO^3 + 2(H,ZH^4,CO^3) + 2Aq$. A compound of one atom of neutral carbonate No. 2], two atoms of bicarbonate No. 4], and two atoms of water. Gmelin's sesquicarbonate of ammonia with five atoms of water $= 2NH^3, 3CO^2, 5HO$.

When the sesquicarbonate No. 5] is in solution in water, it may be considered to be constituted as follows: $2(H,ZH^4,CO^3) + ZH^4,ZH^4,CO^3$.

9]. $2(H,ZH^4,CO^3) + Aq$.

10]. $4(H,ZH^4,CO^3) + Aq$.

The bicarbonate of ammonia No. 4] combined with a little water of crystallisation.

11]. $ZH^4,ZH^4,CO^3 + 6(H,ZH^4,CO^3) + 5Aq$. A compound of six atoms of bicarbonate of ammonia with one atom of neutral carbonate and five atoms of water. Gmelin's seven-fourths carbonate of ammonia $= 4NH^3, 7CO^2, 12HO$, or probably $= NH^3,HO,CO^2 + 3(NH^3,HO,2CO^2) + 8HO$.

12]. $8(H,ZH^4,CO^3) + CO^2 + 2Aq$.

Eight atoms of bicarbonate of ammonia with one atom of carbonic acid and two atoms of water. Gmelin's nine-fourths carbonate of ammonia $= 4NH^3,9CO^2,10HO$. Produced by evaporating the salt No. 5] over oil of vitriol in vacuo. Probably only a mixture.

It appears from this investigation that the carbonates of ammonia when in solution in water consist of the neutral carbonate No. 2] or the bicarbonate No. 4], or mixtures of these two normal salts; that the sesquicarbonate No. 5] when in solution contains two atoms of bicarbonate and one atom of neutral carbonate, and that the various salts upon being crystallised take up water, and when sublimed lose water, and are partly changed into amidogen salts. The instability of the carbonates of ammonia, and their great tendency to combine with one another, give rise to a series of complicated formulæ; but the theory of their constitution is very simple.

The practice of representing multiple salts as containing all their bases in a clump, directly combined with all their acids in another clump, is one of those vicious practices grown out of the theory of "acids" and "bases," which have produced great confusion in chemical theories, and much impeded the progress of organic chemistry. While the carbonates of ammonia may all be represented as multiple salts containing the neutral carbonate, the bicarbonate, and the amidogen salt No. 1], *i. e.* the so-called carbamate, we find Gmelin representing them by such formulæ as these:

$$\begin{array}{l|l}
2NH^3 + 1HO + 2CO^2 & 4NH^3 + 4HO + 5CO^2. \\
2NH^3 + 2HO + 3CO^2 & 2NH^3 + 5HO + 3CO^2. \\
4NH^3 + 5HO + 5CO^2 & 4NH^3 + 10HO + 9CO^2. \\
 & 4NH^3 + 12HO + 7CO^2.
\end{array}$$

These formulæ show us the *materials* with which the salts are prepared, or the *products* which result from their decomposition, but no power of belief in the truth of the doctrine of combination in multiple proportions can give plausibility to the notion that we have here before us true representations of the proximate constitution of the different carbonates of ammonia to which these formulæ refer.

The Carbamates.

If we suppose the neutral carbonate of ammonia No. 2] = ZH^4,ZH^4,CO^3, to be deprived of an atom of water, we have as the result the compound ZH^4,ZH^2,CO^2, which I have described as No. 1] of the carbonates of ammonia. If we suppose the salt to be deprived of a second atom of water, it is then reduced to ZH^2,ZH^2,CO, which is equal to ZH^4,CNO, the last of these formulæ representing cyanate of ammonia, and the preceding one carbamide, both of which compounds have been already fully discussed at pages 221 and 338.

If, on the other hand, we suppose an atom of water to be abstracted from an atom of bicarbonate of ammonia, the resulting product is H,ZH^2,CO^2; since

$$H,ZH^4,CO^3 - HHO = H,ZH^2,CO^2.$$

This product does not appear among the many carbonates of ammonia, nor has it been produced by any experiment whatever. Nevertheless it forms an imaginary acid, which chemists have agreed to call *Carbamic acid*, and in which it is assumed that the amidogen and the carbonic acid form together a conjugated acid which is in combination with a replaceable atom of basic hydrogen = $H^r + ZH^2,CO^2$, or $H^rO + ZH^2,CO$. According to this theory, when H^r is replaced by a basic radical, we have a *Carbamate*, of which kind of salt the following may serve as examples:

ZH^4,ZH^2,CO^2 = Carbamate of ammonia.
CH^3,ZH^2,CO^2 = Carbamate of methyl, or urethylane.
C^2H^5,ZH^2,CO^2 = Carbamate of ethyl, or urethane.
C^5H^{11},ZH^2,CO^2 = Carbamate of amyl, or amylurethane.
C^4H^9,ZH^2,CO^2 = Carbamate of butyl, or butylic urethane.

The view which it seems necessary to take of these salts, if we retain the idea of the existence of carbamates, is, that they are direct compounds of oxamide with oxides of the positive radicals. Thus: $ZH^4O + ZH^2CO$, and $CH^3O + ZH^2CO$. That appears to be not an unlikely composition for the carbamate of ammonia, described above as No. 1 of the carbonates of ammonia; but as respects the other salts, where we have no second atom of azote to deal with, this composition seems to be less probable than that of terbasic cyanates, and I have accordingly included the above four urethanes among the terbasic cyanates: see Nos. 14, 17, 19, and 20 in that series. This operation enables us to dispense with the hypothetical carbamic acid, which, having the theoretical composition of one atom of ammonia combined with one atom of carbonic acid, will probably never be produced, for the same reason that it is impossible to form the terbasic cyanic acid. See page 348. Even the carbamate of ammonia can be represented as a probable member of the group of terbasic cyanates, as I have shown at No. 26 in that series: $ZH^4,ZH^2,CO^2 = H,H,ZH^4; CNO^2$.

The Ureides.

1. $ZH^3,C^2H^3; CyO^2$ . . . . Acetylam cyanete.
2. $ZH^3,C^4H^7; CyO^2$ . . . . Butyrylam cyanete.
3. $ZH^3,C^5H^9; CyO^2$ . . . . Valerylam cyanete.
4. $ZH^3,C^7H^5; CyO^2$ . . . . Benzylam cyanete.

BIAMIDOBENZOIC ACID.

5. $ZH^3,C^6H^5; CyO^2$ . . . . Phenylam cyanete.

The ureides differ from the compound ureas by containing two atoms of oxygen instead of one atom. That is the main difference. The ureides all contain acid radicals in their ammoniums. The ureas sometimes contain acid radicals, but in general they contain basic radicals. According to Miller (*Elements of Chemistry*, iii. 617), the ureides are "salts of urea from which the elements of water have been abstracted;" but if we look at the salts of urea formulated in the Table at page 343, Nos. 19 to 27, we shall be puzzled to find a single example of a salt of urea, which is convertible into a ureide by the abstraction of the elements of water. Indeed, as every ureide is equivalent to an entire compound urea + O^1, it is evidently impossible to convert a compound urea into a ureide by abstracting from it the elements of water.

The ureides No. 1 to No. 4 were formed by Zinin and Moldenhauer by acting on urea with oxychlorides of acid radicals. Thus:

$$ZH^4,CyO + C^2H^3,ClO = ZH^3,C^2H^3; CyO^2 + HCl.$$

$$\begin{array}{ccccccc} \text{Ammona} & + & \text{Acetyla} & = & \text{Acetylam} & + & \text{Hydra} \\ \text{cyanate.} & & \text{chlorate.} & & \text{cyanate.} & & \text{chlora.} \end{array}$$

Nos. 2, 3, and 4 were formed in the same manner.

According to this view of the composition of the ureides, they are Monobasic Cyanetes, which form a remarkable contrast with the Terbasic Cyanetes; there being to the same quantity of cyanogen combined with the same quantity of oxygen, in the salts of one series, one basic radical, and in those of the other series three basic radicals:

$M,M,M; CyO^2$ = Terbasic cyanate. | $ZH^4; CyO^2$ = Ureide.

USUAL NAMES AND FORMULÆ OF THE UREIDES.

$$\left.\begin{array}{ll} 1]. \text{ Acetureide} & = H^3, C^4H^3O^2,N^2C^2O^2 \\ 2]. \text{ Butyrureide} & = H^3, C^8H^7O^2,N^2C^2O^2 \\ 3]. \text{ Valerureide} & = H^3,C^{10}H^9O^2,N^2C^2O^2 \\ 4]. \text{ Benzureide} & = H^3,C^{14}H^5O^2,N^2C^2O^2 \end{array}\right\} \textit{Miller.}$$

Gerhardt's names are—1], Acetyl-urea; 2], Butyryl-urea; 3], Valeryl-urea; 4], Benzoyl-urea. He gives two sets of formulæ, both in tome iv. of his *Traité de Chimie.*

At page 765.	At page 886.
1]. $C^3H^6N^2O^2 = N^2\left\{\begin{matrix} CO \\ C^2H^3O \\ H^3 \end{matrix}\right.$	1]. $C^6H^6N^2O^4 = \left.\begin{matrix} NCyH^3O \\ C^4H^3O^2.O \end{matrix}\right\}$
2]. $C^5H^{10}N^2O^2 = N^2\left\{\begin{matrix} CO \\ C^4H^7O \\ H^3 \end{matrix}\right.$	2]. $C^{10}H^{10}N^2O^4 = \left.\begin{matrix} NCyH^3O \\ C^8H^7O^2.O \end{matrix}\right\}$
3]. $C^6H^{12}N^2O^2 = N^2\left\{\begin{matrix} CO \\ C^5H^9O \\ H^3 \end{matrix}\right.$	3]. $C^{12}H^{12}N^2O^4 = \left.\begin{matrix} NCyH^3O \\ C^{10}H^9O^2.O \end{matrix}\right\}$
4]. $C^8H^8N^2O^2 = N^2\left\{\begin{matrix} CO \\ C^7H^5O \\ H^3 \end{matrix}\right.$	4]. $C^{16}H^8N^2O^4 = \left.\begin{matrix} NCyH^3O \\ C^{14}H^5O^2.O \end{matrix}\right\}$

Two authors thus supply us with five formulæ for each of the ureides. We have the clump formulæ, both with large and with small atoms of C and O; we have the model of water, including in each example the impossible-ammonium $NCyH^3$; we have the double type ammonia; and finally, we have a series of formulæ formed according to no type and after no model.

Gerhardt quotes the following decompositions by heat as illustrating the composition of these compounds:

$$\begin{array}{cccc} 3C^6H^6N^2O^4 & = Cy^3H^3O^6 & + & 3C^4H^5NO^2. \\ \text{Acetyl-urea.} & = \text{Cyanuric acid.} & + & \text{Acetamide.} \end{array}$$

$$\begin{array}{ccccc} 3N^2\left\{\begin{matrix} CO \\ C^2H^3O \\ H^3 \end{matrix}\right. & = & N^3\left\{\begin{matrix} (CO)^3 \\ H^3 \end{matrix}\right. & + & 3N\left\{\begin{matrix} C^2H^3O \\ H \\ H \end{matrix}\right. \\ \text{Acetyl-urea.} & & \text{Cyanuric acid.} & & \text{Acetamide.} \end{array}$$

$$\begin{array}{cccc} 3C^{16}H^8N^2O^4 & = Cy^3H^3O^6 & + & 3C^{14}H^7NO^2. \\ \text{Benzoyl-urea.} & = \text{Cyanuric acid.} & + & \text{Benzamide.} \end{array}$$

According to the radical theory, these decompositions can be represented in a far simpler manner:

$ZH^3,C^2H^3 ; CyO^2$ = $H,CylO$ + $ZH,C^2H^3 ; H.$
Acetylam cyanete = Hydra cyanylate + Acetylac hydra.

$ZH^3,C^7H^5 ; CyO^2$ = $H,CylO$ + $ZH,C^7H^5 ; H.$
Benzylam cyanete = Hydra cyanylate + Benzylac hydra.

The Biamidobenzoic Acid, which I have marked as No. 5 in the Table of Ureides:

$= ZH^3,C^6H^5 ; CyO^2$ Phenylam cyanete,

has been formulated in this work at No. 472, page 254, as a nitrete $= ZH^3,C^7H^5 ; NO^2$. See the notice of the compound and reference made to the discoverer's memoir. The formula given by him is $C^{14}H^4(NH^2)^2O^4$, which signifies nothing, and which is capable of so many re-arrangements, that, in the absence of a more extended account of the chemical reactions of the compound than he has yet given, one can settle it nowhere with certainty. It is only certain, that the substance has no claim to the character of an acid. If it contains benzyl, it is probably a nitrete. If it contains phenyl, it is more likely a monobasic cyanete.

The Allophanates.—Tetrabasic Cyanates.

In accounting for the composition of the different kinds of phosphates, I have shown (page 139) that what are termed *bibasic* phosphates are compounds of monobasic phosphates with tribasic phosphates, and that they therefore contain four basic radicals and two acid radicals. In the same way, other tribasic salts combine with their corresponding monobasic salts, and produce compounds, each of which, like the tribasic phosphates, contains four basic and two acid radicals, and which may be called either bibasic or tetrabasic salts, according as we speak in reference to one or to two atoms of their respective acids.

Among the acids which produce double salts of this description, I think we may place the cyanic acid. The compounds to be cited in evidence of the propriety of this suggestion are not very numerous, but it is probable that their number will speedily increase if this suggestion is found to bear uninjured that strict examination, which all suggestions of this description are foredoomed to undergo.

The structure of a tetrabasic cyanate may be shown thus:

Analytical formula. Synoptical formula.

$$\left\{\begin{array}{r} C^2H^5,CNO \\ H,HO + H\ ,CNO \end{array}\right\} = H,H,H,C^2H^5 ; Cy^2O^3.$$

The strongest objection to this theory exists in the fact that, in the presence of four positive radicals, the two atoms of azote might be expected to produce two amidogens, and leave the carbon to take up the oxygen. The above compound would then assume the following form:

$$\left\{\begin{array}{c} ZH^2;\ CO \\ ZH,C^2H^5;\ COO \end{array}\right\}$$

This is an amidogen salt, agreeing to a certain extent with the oxamates described at page 226, but differing from those salts by having a vice-ammon instead of a non-azotised radical in the oxalate, which, however, is a difference which renders the existence of such an amidogen salt improbable.

Table of Allophanates.

1.	$H,H,H,C^2H^5\ ;\ Cy^2O^3$ . . .	Hydrine ethyla cyanenite.
2.	$H,H,H,C\,H^3\ ;\ Cy^2O^3$ . . .	Hydrine methyla cyanenite.
3.	$H,H,H,C^5H^{11}\ ;\ Cy^2O^3$ . . .	Hydrine amyla cyanenite.
4.	$H,H,H,Ba\ ;\ Cy^2O^3$ . . .	Hydrine baryta cyanenite.

BIURET.

5.	$H,H,H,ZH^4\ ;\ Cy^2O^3$ . . .	Hydrine ammona cyanenite.

The first four of the salts in this Table have received a variety of names, but at present they are called Allophanates. The last-named salt is called Biuret, or bicyanate of ammonia.

1]. $H^3,C^2H^5;\ Cy^2O^3$. This salt is produced when the vapour of hydrated cyanic acid is passed into alcohol or ether:

$$H,CNO + H,CNO + H,C^2H^5O.$$

Discovered by Liebig in 1846. It was originally called the Ureo-carbonate of ethyl, and was assumed to contain the ureo-carbonic acid, which Gmelin (*Handbook*, vii. 377) describes as $C^2Ad^2O^2,2CO^2 = C^4N^2H^4O^6$. No such acid is known, and subsequently Liebig and Wöhler ascribed to this salt the name of Allophanate of ethyl, or Allophanic ether, which it still bears. Gmelin's formula for it is $C^8N^2H^8O^6 = C^4H^5O,C^4N^2H^3O^5$. Gerhardt's formula is $C^4H^3(C^4H^5)N^2O^6$. When decomposed by heat, the allophanic ether produces alcohol and cyanuric acid: $H^3,C^2H^5;\ Cy^2O^3 = H,C^2H^5O + 2HCylO$.

The Allophanic Acid, which is assumed to be present in this salt, but which has no separate existence, has these formulæ assigned to it:

$$C^4N^2H^4O^6 = C^4Ad^2O^2,O^4,\ \textit{Gmelin.}$$

$$\left.\begin{array}{r} C^2O^4,NH^2CyO \\ HO \end{array}\right\}\ \textit{Gerhardt.}$$

$HO,C^2H^3N^2O^2,C^4O^5$, *Miller.*
$NH^2CO.CO^2,HO,(C^2NHO^2)$, *Hofmann.*
$HO.C^4N^2H^3O^5$, *Kolbe.*

There appears to me to be little probability of truth in any of these assumptions. The non-isolation of allophanic acid has been accounted for by assuming that when it is separated from its salts by a stronger acid, it immediately decomposes into carbonic acid and urea. I shall examine this explanation in the note to the barytic salt, No. 4].

2]. $H^3,CH^3;\ Cy^2O^3$. This compound is formed by passing the vapour of hydrated cyanic acid into pure wood spirit:

$$H,CyO + H,CyO + H,CH^3O.$$

Discovered by Richardson in 1837; then called Ureo-carbonate of methyl, and afterwards called Allophanate of methyl. The theory is the same as that of the last example.

3]. $H^3,C^5H^{11};\ Cy^2O^3$. Formed in the same manner as the preceding salts, by passing the vapour of cyanic acid into hydrated oxide of amyle:

$$H,CyO + H,CyO + H,C^5H^{11}O.$$

When heated, it falls into its original constituents, save that the cyanic acid becomes cyanuric acid.

4]. $H^3,Ba;\ Cy^2O^3$. This salt is produced by acting on a solution of allophanic ether, No. 1], by a cold solution of hydrate of barytes:

$$\left.\begin{array}{l}\text{No. 1]} \;=\; H^3,C^2H^5;\ Cy^2O^3\\ \text{Barytic water} \;=\; Ba;\ HO\end{array}\right\} = \left\{\begin{array}{ll}H^3,Ba;\ Cy^2O^3 & = \text{No. 4].}\\ C^2H^5;\ HO & = \text{Alcohol.}\end{array}\right.$$

When the solution of the barytic salt No. 4] is heated, the products are as follow:

$$\left.\begin{array}{c}H^3,Ba;\ Cy^2O^3\\ H^3,Ba;\ Cy^2O^3\\ H,HO\end{array}\right\} = \left\{\begin{array}{ll}Ba,Ba;\ CO^3 & = \text{Carbonate of barytes.}\\ CO^2 & = \text{Carbonic acid.}\\ \left.\begin{array}{r}ZH^4,CyO\\ ZH^4,CyO\end{array}\right\} & = \text{Urea, 2 atoms.}\end{array}\right.$$

When the barytic salt is acted on by a strong acid, it disengages carbonic acid with brisk effervescence, and produces urea. Neither ammonia nor free cyanic acid are disengaged:

$$\text{No. 4].}\left\{\begin{array}{r}Ba,CNO\\ H,H,H,CNOO\\ H,SOO\end{array}\right\} = \left\{\begin{array}{r}ZH^4,CNO\\ COO\\ Ba,SOO\end{array}\right.$$

This decomposition is quite in accordance with the general action of hydrated sulphuric acid upon the cyanates.

It is commonly stated that, when allophanic acid is separated from its salts by a stronger acid, it cannot be retained in an isolated state, because it has the property of immediately decomposing into carbonic acid and urea. The *ideal* of allophanic acid is formed on certain properties belonging in part to ammonia, and in part to cyanic acid. The hydrated allophanic acid, corresponding to the allophanates described in the above Table, should have the formula $H,H,H,H;\ Cy^2O^3$. It is easy to foresee what must occur if this acid was set free in an aqueous solution by the action of hydrated sulphuric acid on the barytic salt No. 4]. I will put the reaction into the form of an equation:

$$\left.\begin{array}{r}H^3,Ba;\ Cy^2O^3\\ H;\ S\ O^2\end{array}\right\} = \left\{\begin{array}{l}H^4;\ Cy^2O^3\\ Ba;\ S\ O^2\end{array}\right.$$

That is the first reaction. But the following would immediately follow:

$$H^4,Cy^2O^3 = ZH^4,CyO + CO^2.$$

The solution would then be ready to suffer any of the reactions described under the article relating to the ureas.

It is evident, throughout these reactions, that we have to deal with salts of cyanic acid, and with nothing else, and that there is no evidence of the existence of an allophanic acid answering to any of the six formulæ which I have cited above from the writings of different chemists.

5]. $H^3,ZH^4;\ Cy^2O^3$. This compound, commonly called Biuret, and sometimes Bicyanate of ammonia, has not been included in the list of Allophanates. Miller gives it these two formulæ: $C^4H^5N^3O^4, 2Aq = HO,H^4NO, 2CyO, 2\ aq$. It is prepared by keeping urea for some time in a melted state at the temperature of 300°. There is a simultaneous production of ammonia, cyanuric acid, and melanuric acid.

When the salt No. 5] is strongly heated, it is decomposed into ammonia, cyanuric acid, and water:

$$\begin{array}{rcccccc} H^3,ZH^4;\ Cy^2O^3 & = & 2H,CylO & + & ZH^2H & + & HHO. \\ \text{Biuret.} & = & \text{Cyanuric acid} & + & \text{Ammonia} & + & \text{Water.}\end{array}$$

With this section, I close my inquiry into the Theory of the Azotic Radicals.

The Doctrine of Polyatomic Alcohols.

THE doctrine of polyatomic alcohols is founded upon the properties of a substance described by M. Wurtz (*Comptes Rendus*, July, 1856) under the name of *glycol*, and upon those of some compounds of *glycerin* which have been investigated by M. Berthelot (*Ann. de Chimie*, iii., xli. 216). The polyatomic alcohols are said to possess the properties of uniatomic alcohols, but to have the power of combining with more than one equivalent of acid. Glycol is called a *Biatomic* alcohol and glycerin a *Teratomic* alcohol. Professor Miller, the President of the Chemical Society, in his Annual Address to that body in March, 1857, described "WURTZ's *brilliant discovery of the biatomic alcohols, of which glycol is the type*," as one of the chemical memorabilia of the past year. I am therefore bound to notice this new and important doctrine.

Glycol, the Biatomic Alcohol.

According to M. Wurtz (*loc. cit.*), glycol is prepared by acting on the iodide of ethylene, $C^4H^4I^2$ (the iodised compound corresponding to Dutch liquid) by dry acetate of silver; one equivalent of the former to two equivalents of the latter. There is a disengagement of carbonic acid gas and olefiant gas; iodide of silver is formed, and the resulting mixture is submitted to distillation. The product then obtained is called by Wurtz the *diacetate of glycol*, and is said to result from the reaction depicted in the following equation:

$$C^4H^4I^2 + 2\begin{pmatrix} C^4H^3O^2 & O^2 \\ Ag & \end{pmatrix} = 2AgI + \left.\begin{matrix} C^4H^4 \\ C^4H^3O^2 \\ C^4H^4O^2 \end{matrix}\right\} O^4$$

Iodide of ethylene.	Acetate of silver.	Iodide of silver.	Binacetate of glycol.

[In this equation, C = 6, O = 8.]

Before proceeding farther with my notes from M. Wurtz, let me draw the reader's attention to the fact that every article in this equation is quoted in *double proportions*. We may ask, why are these double quantities necessary? Why not make use of single proportions? We have no evidence that iodide of ethylene is constituted thus: $C^4H^4I^2$. It may be formed thus: C^2H^2I. In chemistry, what is true of double proportions ought to be true of single proportions; for nature acts the same upon grains as upon tons. I will reduce the ingredients that are named in the above equation uniformly to single proportions, correct the atomic weights of C and O, and put the equation into the form that I have commonly used throughout this volume. It then reads thus:

$$\begin{array}{ccccccc} CH^2,I & + & Ag,C^2H^3O^2 & = & Ag,I & + & CH^2,C^2H^3O^2. \\ \text{Vinyla} & & \text{Argenta} & & \text{Argenta} & & \text{Vinyla} \\ \text{ioda.} & & \text{acetylete.} & & \text{ioda.} & & \text{acetylete.} \end{array}$$

This simple operation produces a magical effect. The glycol vanishes! Instead of binacetate of diatomic glycol, we see only neutral acetate of uniatomic vinyl.

When a uniform reduction in the quantities of all the ingredients concerned in a chemical reaction makes a fundamental change in the *nature* of the products—other conditions being alike—the reaction is one that demands a careful investigation. We cannot place unexplained mysteries in the rank of established truths. It would be a new axiom in philosophical chemistry to assume that Nature, operating upon 200 grains of a mixture, produces other results than when it operates upon 100 grains; that when it acts upon two atoms of a mixture, the products are not the same as when it acts upon one atom. We must make a clear distinction between effects that are produced by natural operations and those which arise from the management of figures arranged in equations.

I return to M. Wurtz: "If it is true that this body [*i.e.* the binacetate of glycol] contains the elements of two equivalents of acetic acid, or, if you please, two equivalents of the radical acetyle [*i. e.* $C^4H^3O^2$], as indicated by the formula, it is evident that, when it is decomposed by the agency of alkalies, it ought to give two equivalents of acetic acid for each equivalent of matter decomposed. This fundamental property has been established by the following experiment."

I do not quote the experiment because I do not dispute the fact. As much of the acetate of vinyl as contains two equivalents of acetyle must necessarily yield to experiment two equivalents of acetic acid; but that fact respecting the acid does not prove the proposed doctrine respecting the base, namely—that C^2H^4 represents *One Radical*—that two atoms of vinyl make one atom of glycol.

M. Wurtz finds that by distilling acetate of glycol with hydrate of potash, *pure glycol* is produced. According to my notation this reaction would be represented as follows:

$$\begin{array}{ccccccc} CH^2,C^2H^3O^2 & + & KHO & = & K,C^2H^3O^2 & + & H,CH^2O. \\ \text{Vinyla} & \multirow{2}{*}{+} & \text{Potassa} & \multirow{2}{*}{=} & \text{Potassa} & \multirow{2}{*}{+} & \text{Hydra} \\ \text{acetylete.} & & \text{hydrate.} & & \text{acetylete.} & & \text{vinylate.} \end{array}$$

But M. Wurtz says that "the method of producing glycol shows that it contains the group C^4H^4—that is to say, olefiant gas, and that its constitution can be expressed by the formula $\left.\begin{matrix} C^4H^4 \\ H^2 \end{matrix}\right\} O^4$, which represents a group of two molecules of water, $\left.\begin{matrix} H^2 \\ H^2 \end{matrix}\right\} O^4$, in which H^2 is replaced by the diatomic radical C^4H^4."

This sentence, *in which every quantity of the acting elements is doubled*, gives rise to the inquiry, Does C^4H^4, or, in corrected numbers, C^2H^4, represent one atom of ethelene or two atoms of vinyl? Why must we double the proportions?

I have, on several occasions in the course of this work, see pages 73, 79, 96, and 108 (which the reader will do well to re-consult), shown the importance of the radical Vinyl, and the necessity of recognising it under the formula CH^2, which represents one volume of gas. I am not aware that any experiment exists, or that any argument has been advanced, which can establish, or even recommend, the formula C^2H^4 as of superior authority or utility to the formula CH^2. For these reasons I consider that ethylene and glycol are non-existent, and that the doctrine of diatomic alcohols, founded upon their assumed existence, and owing its sole authority to the apparent results of equations constructed with double equivalents, is a fallacy. I am, nevertheless, rejoiced that M. Wurtz has discovered the acetate and the hydrate of vinyl, because they serve to show that the character which I assigned to vinyl was not ill-founded. As the Neutral Radical, which stands between the positive and the negative radicals—as hydrogen stands between the metals and the metalloids—its importance cannot be overrated, and it is surprising that chemists have not long since recognised this compound as the key to the system of compound organic radicals.

CONSIDERATIONS RESPECTING THE HYDROCARBONS WHICH CONTAIN AN EVEN NUMBER OF ATOMS OF HYDROGEN.

I copy the following observations from Professor MILLER'S *Elements of Chemistry*, 1857, part iii., page 431:—

"Glycol is derived indirectly from olefiant gas, and there can be no question that the hydrocarbons homologous with olefiant gas will, before long, assume a much more important position in the theory of organic chemistry than has hitherto been assigned to them.

"A paper by Mr. Buff, communicated to the Royal Society by Dr. Hofmann (*Proceedings Roy. Soc.*, viii. 188), contains some important observations on the derivatives of olefiant gas. There are, it must be remarked, two classes of hydrocarbons which yield uniatomic alcohol radicles; one of these is homologous with ethyl, and is represented by the formula (C_nH_{n+1}); this class has been long known and extensively investigated. The second series has only recently attracted the notice of chemists; it is homologous with allyl (C_6H_5), and is represented by the formula (C_nH_{n-1}). Allyl is the only member of this series which has been carefully examined.

"These two groups of hydrocarbons are intimately related to each other, and, probably, the members of the latter series will hereafter be obtained from the former by a general method analogous to that by which Berthelot and De Luca have succeeded in obtaining allyl from glycerin.

"Now, intermediate between these two groups is a third, which has already been long recognised—viz., the group of the hydrocarbons which are homologous with olefiant gas, represented by the general formula ($C_{2n}H_{2n}$); and which, it may be remarked, would be produced by the combination of the *corresponding terms* of the two groups previously alluded to, $C_nH_{n-1} + (C_nH_{n+1}) = (C_{2n}H_{2n})$. It is only recently that these hydrocarbons have been regarded as radicles; yet they are undoubtedly compounds of this nature, but they differ essentially from the radicles of the two other groups, inasmuch as their molecules are *biatomic*, or are capable of displacing two equivalents of hydrogen; whilst the radicles typified by ethyl and allyl are uniatomic, and only represent one equivalent of hydrogen.

"We have already examined the nature of Dutch liquid—a compound, the molecular composition of which was then indicated by the formula (C_4H_3Cl,HCl): the view thus represented harmonizes well with the decompositions which Dutch liquid experiences when treated with potash; but the compound may also be regarded as the result of a combination of the diatomic radicle (C_4H_4) with two equivalents of chlorine, thus $(C_4H_4)''Cl_2$, and as such it may be termed *bichloride of ethylene;* the biatomic character of ethylene $(C_4H_4)''$ being indicated here by the notation ('') affixed to the radicle. Bromine and iodine also combine with olefiant gas, and form corresponding compounds $(C_4H_4)''Br_2$; and $(C_4H_4)''I_2$.

"There can be little doubt but that glycol is the type of a new class of homologous alcohols, each of which will form the starting point of numerous series of collateral derivatives."

REMARKS.—The two classes of compounds which Professor Miller, following MM. Wurtz and Buff, here refers to as having each an odd atom of hydrogen, are those which at page 73 I have distinguished into basic and acid radicals, according as the proportion of hydrogen which each contains is above or below that which is demanded by its carbon for the constitution of a multiple of vinyl. The third class of compounds —namely, those which have an even number of atoms of hydrogen— are characterised by Dr. Miller as being "undoubtedly compounds of the nature of radicles," and as being "biatomic, or capable of displacing two equivalents of hydrogen." This doctrine appears to me to be unsound, for the following reasons:—

1. Because such compounds are frequently not radicals, but salts— namely, pairs of radicals, consisting of hydrides of radicals, or compounds of radicals with each other, of which compounds examples are given at pages 64 and 65 of this work, under the head of *First* and *Second Group of Gaseous Salts.* These compounds have in the state of vapour twice the volume of radicals proper. Every compound formed by a basic radical with an acid radical of the vinyl series, see page 79, and

every compound formed either by a basic or an acid radical of this series with hydrogen, must have an even number of atoms of hydrogen, and yet will not be a radical, but a salt consisting of two radicals.

2. Because there are examples of radicals which contain an even number of atoms of hydrogen, but which are not necessarily biatomic; witness, vinyl = CH^2, and succinyl = C^2H^2; and which do not displace two equivalents of hydrogen. In the vapour of the salts of these radicals, the radical itself measures nothing. See page 96.

3. Because the practice of making uniatomic radicals appear to be biatomic by the crude process of doubling the formulæ is a violation of the law of simplicity, a law which nature always follows, and which science cannot disregard without ceasing to be science.

I might urge many other facts that tell against this doctrine; but the article on compound organic radicals, printed between pages 44 and 81 of this work, anticipates almost every argument that need be advanced. For the reasons stated in those arguments, I do not consider that *there is* A SERIES OF RADICALS *intermediate between the positive and negative radicals* of the vinyl series. Vinyl itself is certainly intermediate; but the compounds that are called the homologues of this radical—namely, the hydrocarbons that are multiples of CH^2 are, for the most part, either hydrides of positive or negative radicals, or salts composed of positive combined with negative radicals; and it is a mistake to ascribe to such double compounds the character of single biatomic radicals.

The bichloride, bibromide, and biniodide of ethylene ought, in my opinion, to be called the neutral chloride, bromide, and iodide of vinyl. The existing evidence is entirely in favour of this assumption. The Dutch liquid is composed of one volume each of chlorine and vinyl (olefiant gas). It has the specific gravity of 49·5 (see page 54), which agrees with the atomic weight of the compound CH^2,Cl, and with one volume of vapour, which is the measure of the chlorine alone, since vinyl measures nothing in its salts. Regnault's bibromide of ethylene has the specific gravity of 94, which agrees with the formula CH^2,Br, and with one volume of vapour. The iodide of ethylene does not produce a gas; but the double formula usually given to it ($C^4H^4I^2$) has nothing to sustain it, and analogy justifies us in describing this salt with greater simplicity and more accuracy as CH^2,I.

There is a sulphide of ethylene ($C^4H^4S^2$) which is equal to CH^2,S = vinyla sulpha, and a sulphohydrate of ethylene ($C^4H^4S^2,2HS$), which may be written $CH^2,S + HS = H ; CH^2 ; S^2$ = hydra vinyla sulphene. This compound produces salts, of which an example may be quoted in $CH^2,S + PbS = Pb ; CH^2 ; S^2$ = plumba vinyla sulphene.

I shall add a short notice of the compounds that have been recently described by MM. Buff and Wurtz.

According to M. Buff, sulphocyanide of potassium decomposes both chloride and bromide of ethylene, and produces sulphocyanide of ethylene, according to the following equation:

$$C_4H_4Cl_2 + 2KCyS_2 = 2KCl + C_4H_4Cy_2S_4.$$

Is it not evident that a result is arrived at here, as in M. Wurtz's argument, by a mere duplication of the ingredients which are named in the formulæ? Avoiding that duplication, the equation is as follows:

$$\begin{array}{ccccccc} CH^2,Cl & + & K,Cy,S^2 & = & KCl & + & CH^2,Cy,S^2. \\ \text{Vinyla} & & \text{Potassa} & & \text{Potassa} & & \text{Vinyla} \\ \text{chlora.} & & \text{cyana} & & \text{chlora.} & & \text{cyana} \\ & & \text{sulphene.} & & & & \text{sulphene.} \end{array}$$

This equation is quite intelligible. We have proof of the existence of vinyl and of its power to act as a radical, and to form salts with chlorine, sulphur, cyanogen, &c. Why are we to renounce vinyl, in order to believe in ethylene, of the existence of which we have less evidence, and then to renounce ethylene to believe in glycol, of the existence of which we have *no* evidence?

The analyses of acetal by M. Stas, and by Baron von Liebig, showed the composition of that compound to be $C^{12}H^{14}O^4$, the atomic weight of which is 118. M. Stas found the specific gravity of the vapour to be 59. Gmelin suggested (*Handbuch der Chemie*, Bd. iv. 807,) that the composition represented a copulated compound of 2 atoms of ether with 1 atom of aldehyde = $2C^4H^5O + C^4H^4O^2 = C^{12}H^{14}O^4$, but he admitted that its behaviour with alkalies and solution of silver rendered the presence of aldehyde improbable; and as it appeared to me to be difficult to account for its atomic measure of two volumes, on the supposition of its containing so many radicals as Gmelin assumed, I suggested, at page 57 of this work, that it might contain ethyl and butyl, but I marked it (?), because I had no facts or authority to support such a suggestion.

M. Wurtz now quotes the composition of acetal as

$$C^{12}H^{14}O^4 = \left.\begin{matrix} C^4H^4 \\ C^4H^5 \\ C^4H^5 \end{matrix}\right\} O^4,$$

which is similar to Gmelin's arrangement of the formulæ, but M. Wurtz considers the compound to be *diethyline of glycol*. By distilling a mixture of alcohol and wood spirit with sulphuric acid and manganese, he prepared two corresponding compounds containing methyl, making together the following series; all of which he considers to be compounds of glycol:

$$\begin{array}{ccc} \text{A.} & \text{B.} & \text{C.} \\ \left.\begin{matrix} C^4H^4 \\ C^4H^5 \\ C^4H^5 \end{matrix}\right\} O^4. & \left.\begin{matrix} C^4H^4 \\ C^4H^5 \\ C^2H^3 \end{matrix}\right\} O^4. & \left.\begin{matrix} C^4H^4 \\ C^2H^3 \\ C^2H^3 \end{matrix}\right\} O^4. \end{array}$$

If now, we correct the atomic weights of C and O, and reduce the duplicate to single quantities, these relations justify the following formulæ:—

$$\begin{array}{lcl} \text{A. } C^2H^5,CH^2O & = & \text{Ethyla vinylate.} \\ \text{B. } \left\{\begin{array}{l} C^2H^5,CH^2O \\ C\,H^3,CH^2O \end{array}\right\} & = & \text{Ethyla vinylate cum methyla vinylate.} \\ \text{C. } C\,H^3,CH^2O & = & \text{Methyla vinylate.} \end{array}$$

The atomic weight of the compound A, which represents Acetal, is according to this formula 59, which agrees with the specific gravity of the vapour on the idea that it forms one volume, the ethyl alone retaining its measure, and the vinyl and oxygen losing theirs. The atomic weight of the compound B is 104. It ought to measure two volumes, and its specific gravity should be $\frac{104}{2} = 52$. Now M. Wurtz found the specific gravity to be 3·475 against air = 1, which is equal to 50·283 against H = 1. The atomic weight of the salt C is 45. Its vapour ought to measure one volume, and its specific gravity ought to be 45. This is equal to spec. grav. 3·11 against air = 1. I do not know what M. Wurtz found it to be. I have a note stating it to be 0·8535, which is evidently an error, either in the *Comptes Rendus* or in my transcription, which I have no opportunity to correct.

"I find," says M. Wurtz, "that other salts of silver are decomposed with great facility by the iodide of ethylene. The benzoate of silver thus gave me an oleaginous neutral compound which is no doubt benzoate of glycol. Consequently, the method which I have described may produce an infinite number of neutral compounds, holding a middle place between the ethers and the fats."

In the absence of exact information, I surmise that the reaction here alluded to is as follows:

$$\begin{array}{ccccccccc} CH^2,I & + & Ag,C^7H^5O^2 & = & Ag,I & + & CH^2,C^7H^5O^2 \\ \begin{array}{c}\text{Vinyla}\\ \text{ioda.}\end{array} & + & \begin{array}{c}\text{Argenta}\\ \text{benzylete.}\end{array} & = & \begin{array}{c}\text{Argenta}\\ \text{ioda.}\end{array} & + & \begin{array}{c}\text{Vinyla}\\ \text{benzylete.}\end{array} \end{array}$$

PROPYLIC GLYCOL AND AMYLIC GLYCOL.

I copy from M. Wurtz:—"I have proved the existence of propylic glycol and amylic glycol.

A.—"By acting upon acetate of silver with bromide of propylene $C^6H^6Br^2$, I produced diacetate of propylic glycol.

$$= \left.\begin{array}{l} C^6H^6 \\ C^4H^3O^2 \\ C^4H^3O^2 \end{array}\right\} O^4 = C^{14}H^{12}O^8.$$

B.—"I prepared diacetate of amylic glycol by acting on bromide of amylene $C^{10}H^{10}Br^2$ with acetate of silver.

$$\left.\begin{matrix}C^{10}H^{10}\\ C^{4}H^{3}O^{2}\\ C^{4}H^{3}O^{2}\end{matrix}\right\} O^{4} = C^{18}H^{16}O^{8}.\text{"}\ \textit{Wurtz.}$$

I confess that I do not understand the terms that are used in this description, or rather, the sense in which the terms are used. Why is the group of atoms C^6H^6 called propylene when in combination with bromine, and propylic glycol when in combination with acetyl and oxygen? Why is the group $C^{10}H^{10}$ called in one form of combination amylene and in another form amylic glycol? Propyl is not present in the first group, because an equivalent of propyl contains H^7; it is propionyl that is present in propylene. Amyl is not present in the last group, because an equivalent of it contains H^{11}. It is valeryl that is contained in amylene.

Overlooking the latitudinarianism of these terms, I will state my view of the reactions which they are used to describe.

Bromide of propylene I consider to be a double salt $= C^3H^5,Br + HBr = H;\ C^3H^5;\ Br^2$ = Hydra propionyla bromen, and the bromide of amylene to be also a double salt $= C^5H^9,Br + HBr = H;\ C^5H^9;\ Br^2 =$ Hydra valeryla bromen. The reactions described by M. Wurtz are, according to my notation, as follow:

$$\text{A.}\left\{\begin{matrix}C^3H^5,Br & + HBr\\ Ag,C^2H^3O^2 & + Ag,C^2H^3O^2\end{matrix}\right\} = \left\{\begin{matrix}C^3H^5,C^2H^3O^2 & + H,C^2H^3O^2\\ AgBr & + AgBr\end{matrix}\right.$$

$$\text{B.}\left\{\begin{matrix}C^5H^9,Br & + HBr\\ Ag,C^2H^3O^2 & + Ag,C^2H^3O^2\end{matrix}\right\} = \left\{\begin{matrix}C^5H^9,C^2H^3O^2 & + H,C^2H^3O^2\\ Ag\ Br & + Ag\ Br\end{matrix}\right.$$

Both of these equations represent ordinary examples of double decompositions.

Supposing the experiments to be correct, which I do not question, in each case, a BINACETATE is produced, but not a binacetate of a *diatomic alcohol*. On the contrary, the first is a binacetate of *propionyl and of hydrogen*, and the second a binacetate of *valeryl and of hydrogen*. There is no evidence of the formation of such things as propylic glycol and amylic glycol; I do not even so much as understand what is meant by those terms; and I cannot admit that phantom compounds which result from the mere duplication of formulæ are to be received as *substantive* compounds, different from those that are exhibited by the same equations when the ingredients are taken in single proportions. To admit that the effects produced by the mere doubling of symbols is sufficient, in the absence of corroborative evidence, to prove the existence of new substances, is to make chemistry a pastime for speculative arithmeticians. It is remarkable that throughout these investigations into the biatomic alcohols, by M. Wurtz, by M. Buff, and by Professor Miller, every result is come at by means of equations that contain duplicate quantities of all the acting substances, and that when you uniformly reduce the quantities from double to single, the biatomic-alcohol theory breaks down; glycol, stripped of its double, is seen to be vinyl; propylic glycol and amylic glycol become shadows of shades; and the whole fabric and its fairy creatures vanish like a mediæval enchanted castle at the touch of truth. The pen destroys them as the pen created them.

Glycerin, the Teratomic Alcohol.

I am so far from considering that GLYCERIN is a *teratomic alcohol*, that I hold it to belong to that class of compounds which are commonly called *terbasic acids*. Instead of being a base which requires three equivalents of acid to neutralise it, I think it is an acid which can neutralise three equivalents of base. The following formulæ are framed in accordance with this opinion:

Group A.

1.	$H,H,H; C^3H^5O^3$	Hydrine glycylite.
2.	$C^3H^5,C^3H^5O^3$	Glycyla glycylite.
3.	$ZH^4,C^3H^5O^2$	Ammona glycylete.
4.	H,C^3H^5	Hydra glycyla.
5.	C^3H^5,I	Glycyla ioda.

Group B.

6.	$H,H,C^2H^3 ; C^3H^5O^4$.	Hydren acetyla glycylote.
7.	$H,H,C^7H^5 ; C^3H^5O^4$.	Hydren benzyla glycylote.
8.	$H,H,C^4H^7 ; C^3H^5O^4$.	Hydren butyryla glycylote.
9.	$H,H,C^{18}H^{33} ; C^3H^5O^4$.	Hydren oleyla glycylote.
10.	$H,H,C^{16}H^{31} ; C^3H^5O^4$.	Hydren palmityla glycylote.
11.	$H,H,C^5H^8 ; C^3H^5O^4$.	Hydren sebamyla glycylote.
12.	$H,H,C^{18}H^{35} ; C^3H^5O^4$.	Hydren stearyla glycylote.
13.	$H,H,C^5H^9 ; C^3H^5O^4$.	Hydren valeryla glycylote.

Group C.

14.	$H,(C^2H^3)^2 ; C^3H^5O^5$ . .	Hydra acetylen glycylute.
15.	$H,(C^2H^5)^2 ; C^3H^5O^3$ . .	Hydra ethylen glycylite.

Group D.

16.	$H,C^3H^5O^2 + (H,C^4H^7O^2)^2$	Hydra glycylete bis hydra butyrylete.
17.	$H,C^3H^5O^2 + (H,C^{18}H^{33}O^2)^2$	Hydra glycylete bis hydra oleylete.

18.	$H,C^3H^5O^2 + (H,C^{16}H^{31}O^2)^2$	Hydra glycylete bis hydra palmitylete.
19.	$H,C^3H^5O^2 + (H,C^{18}H^{35}O^2)^2$	Hydra glycylete bis hydra stearylete.
20.	$H,C^3H^5O^2 + (H,C^5H^9O^2)^2$	Hydra glycylete bis hydra valerylete.

Group E.

21.	$H,(C^4H^7)^2; C^3H^5O^5$	Hydra butyrylen glycylute.
22.	$H,(C^{18}H^{33})^2; C^3H^5O^5$	Hydra oleylen glycylute.
23.	$H,(C^{16}H^{31})^2; C^3H^5O^5$	Hydra palmitylen glycylute.
24.	$H,(C^{18}H^{35})^2; C^3H^5O^5$	Hydra stearylen glycylute.
25.	$H,(C^5H^9)^2; C^3H^5O^5$	Hydra valerylen glycylute.

Group F.

26.	$(C^2H^3)^3; C^3H^5O^6$	Acetyline glycylaze.
27.	$(C^7H^5)^3; C^3H^5O^6$	Benzyline glycylaze.
28.	$(C^4H^7)^3; C^3H^5O^6$	Butyryline glycylaze.
29.	$(C^{18}H^{33})^3; C^3H^5O^6$	Oleyline glycylaze.
30.	$(C^{16}H^{31})^3; C^3H^5O^6$	Palmityline glycylaze.
31.	$(C^{18}H^{35})^3; C^3H^5O^6$	Stearyline glycylaze.
32.	$(C^5H^9)^3; C^3H^5O^6$	Valeryline glycylaze.

Group G.

33.	C^3H^5,ClO	Glycyla chlorate.
34.	$C^3H^5,ClO + HCl$	Glycyla chlorate cum hydra chlora.
35.	$C^3H^5,BrO + HBr$	Glycyla bromate cum hydra broma.
36.	$H,C^3H^5O^2 + HCl$	Hydra glycylete cum hydra chlora.
37.	$H,C^3H^5O^2 + C^3H^5,IO$	Hydra glycylete cum glycyla iodate.
38.	$H,C^3H^5O^2 + C^2H^3,ClO$	Hydra glycylete cum acetyla chlorate.
39.	$H,C^3H^5O^2 + C^7H^5,ClO$	Hydra glycylete cum benzyla chlorate.

Group H.

40.	$\left\{\begin{matrix} H,H,C^3H^5; SO^4 \\ Ca^r; SO^2 \end{matrix}\right\}$	Hydren glycyla sulphote cum calca sulphete.
41.	$\left\{\begin{matrix} Ba^r; PO^3 \\ H^2Ba^r; C^3H^5O^3 \end{matrix}\right\}$	Baryta phosphite cum hydren baryta glycylite.
42.	$H^3; C^3H^3Z^2O^7$	Hydrine zotenic-glycyleze.
43.	$H^3; C^3H^2Z^3O^9$	Hydrine zotinic-glycyloze.

1. H,H,H ; $C^3H^5O^3$ = Hydrine glycylite.

The clump formula commonly given to glycerin is $C^6H^8O^6$. Doubling the atomic weights of C and O, this becomes $C^3H^8O^3$. Chemists have differed greatly in their opinions respecting the proximate constitution of this compound. For the sake of brevity, I will abstain from any historical notice of such opinions, and only describe the theory which I am about to use. I assume, then, that in glycerin there is an acid radical which agrees with the formula C^3H^5, which is Gerhardt's GLYCYL without the oxygen, and I adopt this name to distinguish it.

Glycyl can form salts with one basic radical and two atoms of oxygen, an example of which is given in No. 3, = $ZH^4,C^3H^5O^2$; but hydrated glycylic acid possesses, like hydrated phosphoric acid, the power of forming terbasic salts by combining with water, or with salts formed on the model of water. Thus:

$$H,C^3H^5O^2 + HHO = H^3,C^3H^5O^3 = \text{No. 1.}$$

These three atoms of basic hydrogen are jointly and separately replaceable by other radicals, and these may be either basic or acid radicals, but are more frequently acid than basic.

On glancing over the above Table, it will be seen, that in many cases where the salts are of similar structure, where, for example, *one acid* radical is in combination with *three basic* radicals, there is a remarkable difference in the complement of oxygen, the atoms of which vary according to the series 3, 4, 5, and 6.

In the different orders of phosphates, the quantity of oxygen varies with the number of basic radicals that are present in the salts; but in the glycylites (or glycerides, as they are usually termed), the quantity of oxygen varies while the number of radicals remains unchanged. A little consideration of the facts exhibited in the Table of Examples enables us to explain this peculiarity.

The synoptical formula of terbasic glycylic acid, No. 1 (hydrine glycylite), is H,H,H ; $C^3H^5O^3$. When the atoms of hydrogen are replaced by *basic* radicals, no change occurs in the quantity of oxygen required to complete the glycylite; witness the salt No. 15, which contains two atoms of ethyl, and the formula of which is H,C^4H^5,C^4H^5 ; $C^3H^5O^3$. But when the replacing radicals are such as, under ordinary circumstances, act as *acid* radicals, then each acid radical which goes into the glycylite in the character of a basic radical, carries with it into the salt one additional atom of oxygen. Thus, every salt in Group B has one such *pseudo-basic radical*, and the oxygen is, in consequence, increased from 3 atoms to 4 atoms in each salt. In No. 14 of Group C, and in all the salts of Group E, there are two such radicals, and the oxygen is increased in every instance from 3 atoms to 5 atoms. In the salts of Group F there are three of these radicals, and the quantity of oxygen is, therefore, raised from 3 atoms to 6 atoms. In Group D, each compound contains three acid radicals and three basic radicals, forming three complete salts; and there are present in all only 6 atoms of oxygen, namely, two for each salt, because none of the acid radicals act as basic radicals. In short, so far as this series of salts is concerned, the truth of this important fact is demonstrated.

The property thus shown to be possessed by acid radicals of taking an additional atom of oxygen when they act the part of basic radicals, is not restricted to the radicals which enter into the composition of the glycerides. The inquiry into the constitution of the Anhydrides has taught us otherwise. See page 118. When sulphur, or acetyl, or benzyl, forms salts with hydrogen, or with any basic radical, either metallic or compound, the salts require a complement of two atoms of oxygen; but when the same acid radicals form salts with an acid radical in the place of a basic radical, the oxygen is always increased from two atoms to three atoms. For that reason, all the anhydrous acids have O^3 where the corresponding hydrated acids have O^2, so also all the compound anhydrides, or salts composed of two different acid radicals, have O^3, though the neutral salts of each of the same acid radicals have only O^2 when they contain basic radicals. I am not declaring that this peculiar property of the acid radicals is universal, but it is certainly exercised very frequently, and it deserves more attention than chemists have hitherto been pleased to bestow upon it. In subsequent sections relating to the constitution of polybasic acids, I shall have to speak of it again.

2. $C^6H^5,C^6H^5O^3$. Glycyla glycylite. This compound is the anhydride or anhydrous acid of the glycerine series. Gerhardt calls it the oxide of glyceryle, and Professor Miller characterises it as "the supposed glyceric ether." It is evidently derived, like other anhydrides, by the abstraction of water from the monobasic hydrated glycylic acid.

$$\left.\begin{matrix} H,C^6H^5O^2 \\ H,C^6H^5O^2 \end{matrix}\right\} = \left\{\begin{matrix} C^6H^5,C^6H^5O^3 \\ H,HO \end{matrix}\right. .$$

The preceding paragraph accounts for the presence of O^3 in the anhydride, when the hydrated acid contains only O^2. It shows also the exact accordance of this compound with the compounds called anhydrous acids. I see no reason whatever for imagining it to belong to any other class than this, and I am not surprised at the *doubting* state of mind which led Professor Miller to call this compound the "SUPPOSED" glyceric ether.

3. $ZH^4,C^6H^5O^2$. Ammona glycylete. Professor Miller informs us that, "When an alcoholic solution of bibromhydrin ($C^6H^6Br^2O^2$) [= No. 35 in the above Table] is submitted to the action of gaseous ammonia, the hydrobromate of a new base, *glyceramine*, $C^6H^9NO^4$ (Berthelot and De Luca) is produced, whilst bromide of ammonium is formed.

The correctness of the formula given for this base is however questionable." (*Elements of Chemistry*, iii. 383.)

If we admit that water takes part in the reaction, the equation becomes intelligible, thus:

$$\text{No. }35 = \left.\begin{array}{ll} C^6H^5,BrO & + HBr \\ ZH^3 & + ZH^3 \\ H,HO & \end{array}\right\} = \left\{\begin{array}{l} ZH^4,Br \\ ZH^4,C^6H^5O^2 \\ HBr. \end{array}\right\}$$

The "hydrobromate of a new base" is merely a double salt of hydrobromic acid with the salt No. 3, which is the glyceramine.

4. H,C^6H^5 = Hydra glycyla.
5. C^6H^5,I = Glycyla ioda.

"Glycerine treated with biniodide of phosphorus yields gaseous propylene C^6H^6, a distillate of water and iodopropylene, C^6H^5I, and a residue containing certain oxygen-acids of phosphorus, together with free iodine, undecomposed glycerine, and a trace of red phosphorus. The formation of iodopropylene is due to a reducing action exercised by the PI^2 on the glycerine. The liberation of C^6H^6 appears to be of secondary importance." Berthelot and De Luca (in Gmelin's *Handbook of Chemistry*, ix. 489).

The compounds which are here called propylene and iodopropylene appear to me to be the hydride and the iodide of glycyl; but the variety in the names that are given to hydrocarbon radicals which are isomeric, if not identical, with glycyl is very perplexing. Thus, C^6H^5, occurring as an acid radical in a series of salts, has for some years been called *allyl*. Latterly, Dr. Hofmann (*Proceedings, Royal Society*, viii. 33), has changed the name to *acryl*, although acryl already had fixed upon it the signification of C^6H^3, which formula indicates another radical, produced, like allyl, from glycerine. The term Allyl is therefore overthrown, and we are at liberty to use acryl to signify either C^6H^3 or C^6H^5, which, as these radicals are nearly related, and both producible from glycerine, is a mighty convenient latitude, and highly conducive to perspicuity.[1]

The compound C^6H^5 is also called *mesityl;* it is the radical of *Pseudo-acetic acid*, which has also been called *butyroacetic acid;* it is the radical of *metacetonic acid*; it is the radical of *propylene;* it is the radical of *lactic acid;* it is the radical of *propionic acid* and of *propionic*

---

[1] A new number (26, vol. viii.) of the *Proceedings of the Royal Society*, which has just appeared, contains a paper by Dr. Hofmann, read 15th June, 1857, in which he returns to the old name of Allyl. "It is never too late to mend."

aldide; it is *propionyl;* it is *sixe;* it is the hydride of *tritylene;* it is the radical of *propylal*; &c., &c., &c.

When organic chemists can bring up their languid energies to the point of acknowledging the existence of such things as *radicals*, taking that word in the restricted sense in which it is used in this Essay, one of their first subsequent labours must be that of identifying and discriminating the radicals from one another. Is it creditable to the present race of chemists that we should have nearly a score of names for the hydrocarbon C^3H^5, and that these names should have attached to them characteristics of classes of salts so ill made out that it is impossible to say whether the formula C^3H^5 represents *one thing only*, or *twelve, or twenty different things?*—whether it indicates one performer assuming a variety of characters, like Miss Horton or Mr. Woodin when playing their monopolylogues, or is the representative of a whole company of actors, each possessing an ascertainable individuality?

Such a state of uncertainty should not and need not continue. Looking at it from a business point of view, there is an obvious solution of the problem. The radicals which constitute this mob can either be distinguished from one another, or they cannot. They can be proved to be alike, or to be different. If they *can* be distinguished, it ought to be done, and their characters ought to be laid down with precision; if they *cannot* be distinguished, the useless duplicate names should be abandoned; for it is absurd to retain distinctions in words where there are no differences in things.

At present, I confess that I am unable to identify the radical which in the above formulæ, Nos. 1 to 5, I have called *glycyl*. It may be glycyl; it may be allyl; it may be acryl; it may be lactyl; it may be propionyl. In all probability these five names signify only one thing; and, in the mean time, I assume only that the formula C^3H^5 represents the hydrocarbon which transmigrates through the 44 salts that are named in the above table, and that the word glycyl means this radical.

USUAL NAMES OF THE COMPOUNDS, Nos. 6 to 32.

Group B. 6, Monacetin. 7, Monobenzoicin. 8, Monobutyrin. 9, Monolein. 10, Monopalmitin. 11, Sebacin. 12, Monostearin. 13, Monovalerin.

Group C. 14, Biacetin. 15, Biethylin.

Group D. 16, Bibutyrin. 17, Biolein. 18, Bipalmitin. 19, Bistearin. 20, Bivalerin.

Group E. 21, Bibutyrin. 22, Biolein. 23, Bipalmitin. 24, Bistearin. 25, Bivalerin.

Group F. 26, Teracetin. 27, Terbenzoicin. 28, Terbutyrin. 29, Terolein. 30, Terpalmitin. 31, Terstearin. 32, Tervalerin.

"The most important compounds which result from the action of acids upon glycerin are those termed *glycerides*, which are analogous in composition to the various fats and oils. Berthelot has recently succeeded in forming these bodies by the direct union of the acids with glycerin, and has obtained, in the course of his investigation, not only a large class of these bodies which were not previously known, but has been successful in the attempt to re-combine glycerin with the fatty acids, so as to reproduce several of the natural fats (*Ann. de Chimie*, III., xli. 216). According to the researches of this chemist, stearic, palmitic, and oleic acids, each forms three compounds by its union with glycerin ; the act of combination is, however, attended by the separation of water in each case. . . . The following Table contains a list of these compounds with the formulæ of the decomposition which appears to attend their formation. For the sake of convenience, the formulæ of the hydrated acids are written without indicating the basic water in the usual manner: thus, stearic acid ($HO,C^{36}H^{35}O^{3}$) is written ($C^{36}H^{36}O^{4}$):

				Stearic Acid.		Glycerin.		
Monostearin	=	$C^{42}H^{42}O^{8}$	=	$C^{36}H^{36}O^{4}$	+	$C^{6}H^{8}O^{6}$	−	2HO
Bistearin	=	$C^{78}H^{78}O^{12}$	=	$2(C^{36}H^{36}O^{4})$	+	$C^{6}H^{8}O^{6}$	−	2HO ?
Terstearin	=	$C^{114}H^{110}O^{12}$	=	$3(C^{36}H^{36}O^{4})$	+	$C^{6}H^{8}O^{6}$	−	6HO.

				Acetic Acid.		Glycerin.		
Monacetin	=	$C^{10}H^{10}O^{8}$	=	$C^{4}H^{4}O^{4}$	+	$C^{6}H^{8}O^{6}$	−	2HO
Biacetin	=	$C^{14}H^{12}O^{10}$	=	$2(C^{4}H^{4}O^{4})$	+	$C^{6}H^{8}O^{6}$	−	4HO
Teracetin	=	$C^{18}H^{14}O^{12}$	=	$3(C^{4}H^{4}O^{4})$	+	$C^{6}H^{8}O^{6}$	−	6HO.

"It might have been expected, that in the formation of these compounds the quantity of water separated should have been somewhat different, and that the proportions in each of the three compounds should have been 2HO in the first, 4HO in the second, and 6HO in the third, each equivalent of the hydrated acid losing an equivalent of water, whilst the single equivalent of glycerin, in the act of combination, should lose 1, 2, and 3 equivalents of water, according to the number of equivalents of acid with which it is combined.

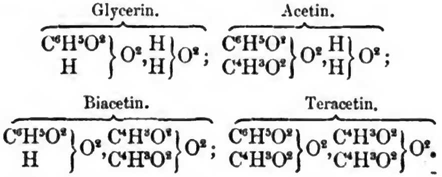
"According to Berthelot, terstearin, terpalmitin, and terolein, are identical with the stearin, palmitin, and olein of the natural fats, and they are produced by the combination of 3 equivalents of the hydrated fatty acids ($C_nH_nO_4$) with 1 equivalent of glycerin, the act of combination being attended with the separation of 6 equivalents of water.

"All these neutral compounds of the fatty acids with glycerin are insoluble in water, but are soluble to some extent in boiling alcohol, and are readily soluble in ether. If treated with concentrated acids, they are decomposed and acidified in the same manner as the natural fats; and they are all saponifiable—that is, they are decomposed, like the natural fats, into a fatty acid and glycerin, when boiled with an alkali. It has been found that whether monacid, biacid, or teracid in composition, these fats are all neutral in their reactions, and, moreover, when decomposed, they all yield glycerin of the same composition and condition of hydration."—Miller (*Elements of Chemistry*, 1857, part iii. 381).

I have quoted only two examples from the Table given by Professor Miller, because these are sufficient to show the amount of information which they contain. They give us the relations of the acids and glycerin to the resulting compounds, but they make no attempt to explain, what we chiefly wish to have explained, the internal constitution of these compounds. Terstearin is merely said to be $C^{114}H^{110}O^{12}$, and we are left to guess, as we can, at the possible proximate constitution of the salt which is represented by this great unhewn block of 236 ultimate atoms.

The following paragraph, which Professor Miller appends as a footnote to his phrase "supposed glyceric ether" (*Elements of Chemistry*, iii. 383), contains the only hints towards a knowledge of the proximate constitution of the glycerides which he ventures to advance:—

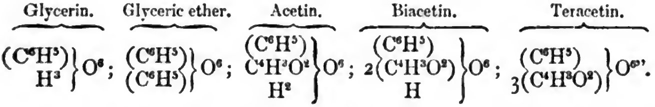
"Glycerin, however, if it be an alcohol, cannot be a monatomic alcohol, but it must be teratomic; in which case it may be formed, as Gerhardt suggests, upon the type of two double molecules of water, and its radicle ($C^6H^5O^2$) may be named *glycyl*, in order to distinguish it from Liebig's *glyceryl* (C^6H^7). The relation of the three acetins to glycerin would then be the following:—



$$\overbrace{\left.\begin{matrix}C^6H^5O^2\\ H\end{matrix}\right\}O^2,\left.\begin{matrix}H\\ H\end{matrix}\right\}O^2}^{\text{Glycerin.}};\quad \overbrace{\left.\begin{matrix}C^6H^5O^2\\ C^4H^3O^2\end{matrix}\right\}O^2,\left.\begin{matrix}H\\ H\end{matrix}\right\}O^2}^{\text{Acetin.}};$$

$$\overbrace{\left.\begin{matrix}C^6H^5O^2\\ H\end{matrix}\right\}O^2,\left.\begin{matrix}C^4H^3O^2\\ C^4H^3O^2\end{matrix}\right\}O^2}^{\text{Biacetin.}};\quad \overbrace{\left.\begin{matrix}C^6H^5O^2\\ C^4H^3O^2\end{matrix}\right\}O^2,\left.\begin{matrix}C^4H^3O^2\\ C^4H^3O^2\end{matrix}\right\}O^2}^{\text{Teracetin.}}.$$

"Wurtz, however, considers glycerin to be formed upon the type of three double molecules of water, $\left.\begin{matrix}H^3\\ H^3\end{matrix}\right\}O^6$; a view which is more consistent with the general theory of these compounds; C^6H^5 being a teratomic radicle, or representing three equivalents of hydrogen, thus:



$$\overbrace{\left.\begin{matrix}(C^6H^5)\\ H^3\end{matrix}\right\}O^6}^{\text{Glycerin.}};\ \overbrace{\left.\begin{matrix}(C^6H^5)\\ (C^6H^5)\end{matrix}\right\}O^6}^{\text{Glyceric ether.}};\ \overbrace{\left.\begin{matrix}(C^6H^5)\\ C^4H^3O^2\\ H^2\end{matrix}\right\}O^6}^{\text{Acetin.}};\ \overbrace{\left.\begin{matrix}(C^6H^5)\\ 2(C^4H^3O^2)\\ H\end{matrix}\right\}O^6}^{\text{Biacetin.}};\ \overbrace{\left.\begin{matrix}(C^6H^5)\\ 3(C^4H^3O^2)\end{matrix}\right\}O^6}^{\text{Teracetin.}}\text{''}.$$

When I look at the real model of water—HHO—and compare its simplicity with the intricacy of these giant formulæ, I marvel at the latitude of interpretation in which organic chemists indulge! While professing to account for the composition of these salts upon their alleged resemblance to the model of water, we have here one chemist extending his model to *four* atoms, and another to *six* atoms of water, and twisting these into a variety of strange and fantastic forms. These are not examples of adherence to a scientific standard, but of the play of a capricious fancy.

The difficulty which Professor Miller starts in regard to the quantity of water which is expelled during the reaction, gives rise to the double set of formulæ which I have given in Groups D and E. The compounds in Group D represent the results of M. Berthelot's analyses; and which have been objected to, not only by Dr. Miller, but by M. Gerhardt, and by Mr. Watts (editor of Gmelin's *Handbook*). The salts of Group E are the (presumed) same compounds formulated according to a suggested correction of Gerhardt's, which consists in deducting HHO from each salt (equal to 2HO according to Dr. Miller's notation). As all the series of salts are formed by heating together the acids and glycerin in closed glass tubes, for different lengths of time and at different degrees of heat, and the effect produced is the gradual formation and separation of water from the anhydrides that are formed simultaneously, it is possible that both sets of salts may be formed, though, certainly, those of Group E seem to be of more probable occurrence than those of Group D.

Let us now see how these various salts agree with the notion that formula No. 1 = H,H,H; $C^3H^5O^3$ represents the true composition of glycerin, according to which formula glycerin is a terbasic acid, and the glycerides are salts in which the so-called fatty acids act the part of bases against glycerin acting as an acid.

The following examples represent, in detail, the reactions which take place when hydrated terbasic glycylic acid is heated with hydrated acetic, butyric, and stearic acids, and with alcohol.

Group B.

$$\left.\begin{array}{lr} & \mathrm{H,H,H;\ C^3H^5O^3} \\ \text{Acetic acid.} & \mathrm{H;\ C^2H^3O^2} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{H,H,C^2H^3;\ C^3H^5O^4} \\ \qquad\mathrm{H;\ HO} \end{array}\right. = \text{No. 6.}$$

$$\left.\begin{array}{lr} & \mathrm{H,H,H;\ C^3H^5O^3} \\ \text{Stearic acid.} & \mathrm{H;\ C^{18}H^{35}O^2} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{H,H,C^{18}H^{35};\ C^3H^5O^4} \\ \qquad\mathrm{H;\ HO} \end{array}\right. = \text{No. 12.}$$

Group C.

$$\left.\begin{array}{lr} & \mathrm{H,H,H;\ C^3H^5O^3} \\ \text{Acetic acid.} & \mathrm{2(H;\ C^2H^3O^2)} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{H,C^2H^3,C^2H^3;\ C^3H^5O^5} \\ \qquad\mathrm{2(H;\ HO)} \end{array}\right. = \text{No. 14.}$$

$$\left.\begin{array}{lr} & \mathrm{H,H,H;\ C^3H^5O^3} \\ \text{Alcohol.} & \mathrm{2(H;\ C^2H^5O)} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{H,C^2H^5,C^2H^5;\ C^3H^5O^3} \\ \qquad\mathrm{2(H,\ HO)} \end{array}\right. = \text{No. 15.}$$

Group D.

$$\left.\begin{array}{r}\text{H,H,H}\,;\ C^3H^5O^3\\ \text{Butyric acid. }2(H\,;\ C^4H^7O^2)\end{array}\right\} = \left\{\begin{array}{l}2(H,C^4H^7O^2) + H,C^3H^5O^2 = \text{No. 16.}\\ \qquad\qquad\qquad\qquad H\,;\ HO\end{array}\right.$$

Group E.

$$\left.\begin{array}{r}\text{H,H,H}\,;\ C^3H^5O^3\\ \text{Butyric acid. }2(H\,;\ C^4H^7O^2)\end{array}\right\} = \left\{\begin{array}{l}H,C^4H^7,C^4H^7 \qquad ;\ C^3H^5O^5 = \text{No. 21.}\\ \qquad\qquad\qquad 2(H\,;\ HO)\end{array}\right.$$

Group F.

$$\left.\begin{array}{r}\text{H,H,H}\,;\ C^3H^5O^3\\ \text{Acetic acid. }3(H\,;\ C^2H^3O^2)\end{array}\right\} = \left\{\begin{array}{l}C^2H^3,C^2H^3,C^2H^3 \qquad ;\ C^3H^5O^6 = \text{No. 26.}\\ \qquad\qquad\qquad 3(H\,;\ HO)\end{array}\right.$$

$$\left.\begin{array}{r}\text{H,H,H}\,;\ C^3H^5O^3\\ \text{Stearic acid. }3(H\,;\ C^{18}H^{35}O^2)\end{array}\right\} = \left\{\begin{array}{l}C^{18}H^{35},C^{18}H^{35},C^{18}H^{35};\ C^3H^5O^6 = \text{No. 31.}\\ \qquad\qquad\qquad 3(H\,;\ HO)\end{array}\right.$$

It will be observed, that in the formation of these compounds there is a gradual progression from the condition of normal hydrated acids to that of perfect anhydrides. Thus, the salt No. 6 is equal to $H,C^2H^3O^2 + H,C^3H^5O^2$, or hydrated acetic acid plus hydrated glycylic acid; and the salt No. 31 is equal to $C^{18}H^{35},C^{18}H^{35}O^3 + C^{18}H^{35},C^3H^5O^3$ or the stearic anhydride plus the compound anhydride of stearyl and glycyl. The other groups are intermediate, according to their deficiency of $\dot{H}HO$.

At page 73 of this work I have given an arbitrary rule for arranging the hydrocarbon radicals in the order of their basicity. According to that rule, the radicals, which form the salts Nos. 6 to 32 in the Table of glycerides, are to be arranged as follows:—

1. Ethyl = C^2H^5
2. Stearyl = $C^{18}H^{35}$
3. Palmityl = $C^{16}H^{31}$
4. Oleyl = $C^{18}H^{33}$
5. Valeryl = C^5H^9
6. Butyryl = C^4H^7
7. Glycyl = C^3H^5
8. Sebamyl = C^5H^8
9. Acetyl = C^2H^3
10. Benzyl = C^7H^5.

This relationship justifies me in placing the radicals of the fatty acids as positive or basic against the radical of glycerine, considered as negative or acid, and in overturning the notions which are commonly attached to the components of the glycerides. I do not mean to say that my arbitrary rule for discriminating positive from negative radicals alone justifies my over-riding the opinions generally entertained on this subject by organic chemists, but that this arbitrary rule leads to results the importance of which justifies my classification. In fact, the notion that glycerine is a teratomic alcohol leads to nothing beyond clump formulæ (save only the crude attempts to explain the compounds by the model of water); whereas the assumption that it is a terbasic acid gives rise to formulæ that are regular, intelligible, and probable.

Let us now examine why it is that the fats, or glycerides, whether monacid, biacid, or teracid, when boiled with potash, all yield glycerin of the same composition and condition of hydration. I will adduce the different stearins as examples:

Monostearin.

No. 12]. $$\left.\begin{array}{r} H,H,C^{18}H^{35}\,;\,C^{3}H^{5}O^{4} \\ K\,;\,HO \end{array}\right\} = \left\{\begin{array}{r} H,H,H\,;\,C^{3}H^{5}O^{3} = \text{No. 1]}. \\ K\,;\,C^{18}H^{35}O^{2} \end{array}\right.$$

Bistearin (according to Gerhardt).

No. 24]. $$\left.\begin{array}{r} H,C^{18}H^{35},C^{18}H^{35}\,;\,C^{3}H^{5}O^{5} \\ K\,;\quad H\ O \\ K\,;\quad H\ O \end{array}\right\} = \left\{\begin{array}{r} H,H,H\,;\,C^{3}H^{5}O^{3} = \text{No. 1]}. \\ K\,;\,C^{18}H^{35}O^{2} \\ K\,;\,C^{18}H^{35}O^{2} \end{array}\right.$$

Terstearin.

No. 31]. $$\left.\begin{array}{r} (C^{18}H^{35})^{3}\,;\,C^{3}H^{5}O^{6} \\ 3(K\,;\,HO) \end{array}\right\} = \left\{\begin{array}{r} H,H,H\,;\,C^{3}H^{5}O^{3} = \text{No. 1]}. \\ 3(K\,;\,C^{18}H^{35}O^{2}) \end{array}\right.$$

Bistearin (according to Berthelot).

No. 19]. $$\left.\begin{array}{r} \left\{\begin{array}{l} H\,;\,C^{18}H^{35}O^{2} \\ H\,;\,C^{18}H^{35}O^{2} \\ H\,;\,C^{3}H^{5}O^{2} \end{array}\right. \\ K\,;\quad H\ O \\ K\,;\quad H\ O \end{array}\right\} = \left\{\begin{array}{r} H,H,H\,;\,C^{3}H^{5}O^{3} = \text{No. 1]}. \\ K\,;\,C^{18}H^{35}O^{2} \\ K\,;\,C^{18}H^{35}O^{2} \\ H\,;\quad H\ O \end{array}\right.$$

These equations prove that every individual radical of the fatty acids takes up K^{1} from KHO (hydrate of potash), and that the quantity of HO thus set free is in all cases exactly sufficient to convert the liberated glycyl into the tribasic glycylic acid, $H^{3},C^{3}H^{5}O^{3}$. The radicals of the fatty acids, which act positively against glycyl, act negatively against metallic radicals and against hydrogen. The equations account for the disposal of every atom which is concerned in each reaction.

The compounds represented in Groups G and H are of much less importance than those which precede them; but I will show briefly that they are not inconsistent with the theory that I have advanced to explain the more important compounds.

Group G. USUAL NAMES. 33, Epichlorhydrin = $C^{6}H^{5}ClO^{2}$. 34, Bichlorhydrin = $C^{6}H^{6}Cl^{2}O^{2}$. 35, Bibromhydrin = $C^{6}H^{6}Br^{2}O^{2}$. See the note to No. 3]. 36, Monochlorhydrin = $C^{6}H^{7}ClO^{4}$. 37, Iodhydrin = $C^{12}H^{11}IO^{6}$. This compound is decomposed by caustic potash, according to the following equation:—

$$\left.\begin{array}{lcr} H,C^{3}H^{5}O^{2} & + & C^{3}H^{5},IO \\ H,C^{3}H^{5}O^{2} & + & C^{3}H^{5},IO \\ K,HO & + & K,HO \\ & + & H,HO \end{array}\right\} = \left\{\begin{array}{lcl} C^{3}H^{5},C^{3}H^{5}O^{3} & = & \text{No. 2]}. \\ 2(H^{3},C^{3}H^{5}O^{3}) & = & \text{No. 1]}. \\ 2(K\,,I) & & \end{array}\right.$$

38, Acetochlorhydrin = $C^{10}H^{9}ClO^{6}$. 39, Benzochlorhydrin = $C^{20}H^{11}ClO^{6}$.

Group H. Usual Names. 40, Sulphoglycerate of Lime = $CaO, C^6H^7O^5,2SO^3$, *Miller*. Gerhardt's formula for the "acid," which he calls monobasic, is $O^3\left\{\begin{matrix}C^3H^5O\\ SO^2\\ H^3.\end{matrix}\right\}$. There are similar salts with Ba, Ag, and Pb instead of Ca. The formula No. 40 is founded upon the notion that the compound is a double sulphate ($Ca,SO^2 + H,H,C^3H^5; SO^4$), the salt Ca,SO^2 is neutral and $H,H,C^3H^5; SO^4$ is terbasic. There are four atoms of oxygen in the latter instead of two; one atom extra because it is terbasic acid, and another atom because it contains an acid radical acting as a basic radical.

41, Phosphoglycerate of Barytes = $C^6H^6Ba^2O^6,HO,PO^5$, *Gmelin*. Gerhardt gives the following formula to phosphoglyceric acid, which he calls bibasic:—$O^4\left\{\begin{matrix}C^3H^5O\\ PO\\ H^4.\end{matrix}\right\}$. 42, Nitroglycerine = $C^6H^6(NO^4)^2O^6$, *De Vrij*. 43, Nitroglycerine = $C^6H^5(NO^4)^3O^6$, *Railton*. When boiled with aqueous potash, these compounds produce glycerine and nitrate of potash:—

$$\text{No. 42]. }\left.\begin{matrix}H^3,C^3H^3Z^2O^7\\ (K,HO)^2\end{matrix}\right\} = \left\{\begin{matrix}2(KNO^3)\\ H^3,C^3H^5O^3 = \text{No. 1].}\end{matrix}\right.$$

$$\text{No. 43]. }\left.\begin{matrix}H^3,C^3H^2Z^3O^9\\ (K,HO)^3\end{matrix}\right\} = \left\{\begin{matrix}3(K,NO^3)\\ H^3,C^3H^5O^3 = \text{No. 1].}\end{matrix}\right.$$

These two compounds, Nos. 42, 43, have been described as belonging to the salts of zotic radicals described at page 132: but I shall show, at page 394, that they admit of another and a better interpretation.

The Doctrine of "Polyatomic Alcohols" is now ready for the reader's judgment. I have placed the evidence before him, and he is to decide upon it. My summing up of it is as follows:—

1. There is no such thing as Glycol—meaning thereby a radical different from Vinyl; a radical that can produce a binacetate, but not a monacetate.

2. There is consequently no biatomic alcohol, because the visionary glycol is the only evidence to support the doctrine of biatomic alcohols.

3. It is easy to account for the composition of the glycerides on the assumption that glycyl is the radical of a terbasic acid.

4. It is impossible to give a rational account of the composition of the glycerides on the assumption that glycyl is the radical of a teratomic alcohol.

5. There is consequently no evidence to support the theory of teratomic alcohols.

6. The Doctrine of Polyatomic Alcohols is a delusion.

Recent Proceedings in the French Academy of Sciences, respecting the Teratomic Alcohols.

Just as the final proof of the preceding article on POLYATOMIC ALCOHOLS was about to be sent to press, I read in a French scientific newspaper (*La Lumière*, 29th August, 1857), the following Article, No. 1. The broad statements respecting the existence of acid quaternions, contained in this Article, and the strong approval of the teratomic-alcohol theory attributed to M. Chevreul, induced me to delay the printing of my Article until the arrival of the *Comptes Rendus* of 17th August, 1857, from which I have extracted the Summary, No. 2. These two papers give the reader the latest experimental researches, and the newest doctrines, on the subject of the teratomic alchohols. After reading them, I sent my Article, as it stood in type, to press, considering it was needless to alter it, because its facts, arguments, and conclusions, were in no respect invalidated by the new discoveries.

No. 1.

"AT THE SITTING OF THE ACADEMY OF SCIENCES, IN PARIS, ON THE 17TH AUGUST, 1857,

"M. Chevreul communicated to the Academy, in the names of the authors, MM. Berthelot and De Luca, a complete treatise on the compounds which glycerine, considered as a teratomic alcohol, produces on combining with chlorhydric, bromhydric, and acetic acids.

"It results from this investigation, that glycerine presents, in comparison with alcohol, precisely the same relations that phosphoric acid presents in comparison with nitric acid. This latter acid forms with bases only a single series of neutral salts, that is to say, the monobasic nitrates; whereas phosphoric acid produces with bases three distinct series of neutral salts, namely, the monobasic metaphosphates, the bibasic pyrophosphates, and the ordinary tribasic phosphates.

"Similarly, alcohol produces with acids only a single series of neutral compounds, namely, the Ethers, formed by the union of one equivalent of alcohol with one equivalent of acid; whereas glycerine forms with acids three distinct series of neutral compounds. Among these compounds, some result from the union of one equivalent of glycerine with a single equivalent of acid, and correspond to the metaphosphates; others result from the union of two equivalents of acid and one equivalent of glycerine, and correspond to the pyrophosphates; whilst, finally, the third class, identic with the natural fatty bodies, result from the action of one equivalent of glycerine with three equivalents of acid, and correspond with the ordinary phosphates.

"MM. Berthelot and De Luca undertook the investigation of a certain number of double and triple compounds, which result from the simultaneous union of one equivalent of glycerine with two or even with three different acids; these complex compounds are so much the more interesting, that their analogues are found among the natural fatty bodies. The compounds of this order are easy of production, it being only necessary to act upon glycerine with several acids at once. The results at which the authors arrived, complete the study of the glycerine compounds, considered as derivatives of a triatomic alcohol, constituting the most complete and most general type which has ever been made known, of the compounds formed by three acids combined with glycerine, either singly, doubly, or triply.

"MM. Berthelot and De Luca have prepared a neutral compound, which contains glycerine, bromhydric acid, and chlorhydric acid; another containing glycerine, chlorhydric acid, and acetic acid; a third, containing glycerine, bromhydric acid, and acetic acid. They have also prepared several intermediate compounds; and, finally, they have procured a compound which contains at the same time glycerine, chlorhydric acid, bromhydric acid, and acetic acid, and which is the first compound ever prepared in which three different acids are combined with a single equivalent of glycerine.

"M. Chevreul earnestly pressed upon the notice of the Academy the importance of this new discovery, declaring it to be unprecedented, and as throwing a flood of light upon the constitution of glycerine."

No. 2.

THE COMPOUNDS FORMED BY GLYCERINE WITH CHLORHYDRIC, BROMHYDRIC, AND ACETIC ACIDS. By MM. BERTHELOT and DE LUCA. *Comptes Rendus*, 17th August, 1857.

"After different attempts to form complex compounds by the successive reactions of two or three distinct acids upon glycerine, we were led, in order to avoid the formation of very complicated mixtures, to cause the acids to act upon the glycerine simultaneously and in the nascent state. We produced the above-named acids in equivalent proportions, and at the cost of the glycerine itself, by treating that body with acetic chloride and acetic bromide. It is known that these last compounds, when treated with water, reproduce acetic acid in company with chlorhydric or bromhydric acid:

$$C^4H^3ClO^2 + 2HO = C^4H^4O^4 + HCl.^1$$

---

[1] In my notation $= C^2H^3,ClO + H,HO = H,C^2H^3O^2 + HCl.$—J. J. G.

"The reaction of these bodies upon glycerine, even when cold, is extremely violent. By operating upon pure glycerine, and sometimes upon glycerine mixed with acetic acid, we have obtained:

Acetodichlorhydrine:

$$C^{10}H^{8}Cl^{2}O^{4} = C^{6}H^{8}O^{6} + C^{4}H^{4}O^{4} + 2HCl - 6HO,$$

a neutral compound, volatile at about 205°C., decomposable by barytes with regeneration of glycerine; by alcohol and chlorhydric acid with formation of acetic ether;

Acetochlorhydrine:

$$C^{10}H^{9}ClO^{6} = C^{6}H^{8}O^{6} + C^{4}H^{4}O^{4} + HCl - 4HO,$$

a neutral body, volatile at about 250° C.;

Diacetochlorhydrine:

$$C^{14}H^{11}ClO^{8} = C^{6}H^{8}O^{6} + 2C^{4}H^{4}O^{4} + HCl - 6HO,$$

a body which volatilizes at about 245° C., and which it is difficult to obtain free from triacetine.

"The acetic bromide gives origin to analogous compounds which it did not appear to be necessary to examine in detail.

"Finally, glycerine, treated by a mixture of equal equivalents of acetic chloride and acetic bromide, has furnished:

Acetochlorhydrobromhydrine:

$$C^{10}H^{8}ClBrO^{4} = C^{6}H^{8}O^{6} + C^{4}H^{4}O^{4} + HCl + HBr - 6HO,$$

a neutral compound, volatile at about 228° C., and the first compound in which three distinct acids have been found combined at the same time with a single equivalent of glycerine.

"According to these facts, and to those which we have already published, the three acids, chlorhydric, bromhydric, and acetic, can, by combining with glycerine, produce at least nineteen distinct neutral compounds, of which the following is a list:—

1. Monochlorhydrine . . . . . $C^6H^7ClO^4 = C^6H^8O^6 + HCl - 2HO$
2. Monobromhydrine . . . . . $C^6H^7BrO^4 = C^6H^8O^6 + HBr - 2HO$
3. Monacetine . . . . $C^{10}H^{10}O^8 = C^6H^8O^6 + C^4H^4O^4 - 2HO$
4. Dichlorhydrine . . . . . . $C^6H^6Cl^2O^2 = C^6H^8O^6 + 2HCl - 4HO$
5. Dibromhydrine . . . . . . $C^6H^6Br^2O^2 = C^6H^8O^6 + 2HBr - 4HO$
6. Chlorhydrobromhydrine . . . $C^6H^6ClBrO^2 = C^6H^8O^6 + HCl + HBr - 4HO$
7. Diacetine . . . . $C^{14}H^{12}O^{10} = C^6H^8O^6 + 2C^4H^4O^4 - 4HO$
8. Acetochlorhydrine . . . . . $C^{10}H^9ClO^6 = C^6H^8O^6 + HCl + C^4H^4O^4 - 4HO$
9. Acetobromhydrine . . . . . $C^{10}H^9BrO^6 = C^6H^8O^6 + HBr + C^4H^4O^4 - 4HO$
10. Trichlorhydrine . . . . . . $C^6H^5Cl^3 = C^6H^8O^6 + 3HCl - 6HO$
11. Tribromhydrine . . . . . . $C^6H^5Br^3 = C^6H^8O^6 + 3HBr - 6HO$
12. Bromhydrodichlorhydrine . . $C^6H^5Cl^2Br = C^6H^8O^6 + 2HCl + HBr - 6HO$
13. Chlorhydrodibromhydrine . . $C^6H^5ClBr^2 = C^6H^8O^6 + HCl + 2HBr - 6HO$
14. Triacetine . . . . $C^{18}H^{14}O^{12} = C^6H^8O^6 + 3C^4H^4O^4 - 6HO$
15. Diacetochlorhydrine . . . . $C^{14}H^{11}ClO^8 = C^6H^8O^6 + HCl + 2C^4H^4O^4 - 6HO$
16. Diacetobromhydrine . . . . $C^{14}H^{11}BrO^8 = C^6H^8O^6 + HBr + 2C^4H^4O^4 - 6HO$
17. Acetodichlorhydrine . . . . $C^{10}H^8Cl^2O^4 = C^6H^8O^6 + 2HCl + C^4H^4O^4 - 6HO$
18. Acetodibromhydrine . . . . $C^{10}H^8Br^2O^4 = C^6H^8O^6 + 2HBr + C^4H^4O^4 - 6HO$
19. Acetochlorhydrobromhydrine . $C^{10}H^8ClBrO^4 = C^6H^8O^6 + \left\{\begin{matrix}HCl\\HBr\end{matrix}\right\} + C^4H^4O^4 - 6HO$

20. Dibutyrosulphurine . . . . $C^{22}H^{19}SO^{12} = C^6H^8O^6 + SO^4H + 2C^8H^8O^4 - 6HO$

[In this Table, H = 1, C = 6, O = 8.]

"This is the most complete type that has ever been developed by experiment of the complex compounds which can be produced by a triatomic alcohol. Combinations of this order are always produced when we act upon glycerine with two acids at once. It was thus that one of us had previously obtained acetochlorhydrine by the simultaneous action of chlorhydric and acetic acids; benzochlorhydrine, valerochlorhydrine, stearochlorhydrine, butyrochlorhydrine, etc. By acting upon glycerine with a mixture of butyric and sulphuric acids, we have obtained a neutral compound which can be considered as a mixture of equal parts of tributyrine and of a glycerine formed conjointly by the two acids, butyric and sulphuric,

The *Dibutyrosulphurine*:

$$C^{22}H^{19}SO^{12} = C^{6}H^{8}O^{6} + 2C^{8}H^{8}O^{4} + SO^{4}H - 6HO.$$

"This explains a great number of facts that are observed in the study of natural fatty bodies, and notably the existence, signalised by MM. Pelouze and Boudet, of certain crystallisable complex products, in which glycerine is combined at the same time with two fatty acids. All these phenomena, the theoretical interpretation of which has hitherto been obscure and incomplete, can now be explained by the properties of polyatomic alcohols, in a manner the most simple and most conformable to analogies.

"To show all the riches—all the variety of compounds—of which this theory permits us to foresee the existence, it suffices to cite the following numbers: glycerine, on combining with n acids in equal equivalents, forms n neutral compounds; with 2 equivalents of these n acids, taken 1 to 1, or 2 to 2, it can form $\frac{n\,(n+1)}{1\,.\,2}$ neutral compounds; with 3 equivalents of these n acids, taken 1 to 1, 2 to 2, 3 to 3, it can produce $\frac{n\,(n+1)\,(n+2)}{1\,.\,2\,.\,3}$ neutral compounds. If we admit the existence of a thousand distinct acids, a number that is certainly below the reality, the multitude of glycerine compounds of the third order will consequently be equal to $\frac{1000\,.\,1001\,.\,1002}{1\,.\,2\,.\,3}$, that is to say, pretty nearly two hundred millions.

"We see to what an almost infinite variety of complex compounds, often analogous to, or identical with, certain natural substances, we can give origin by combining a small number of compounds with the polyatomic alcohols."

If we are to have in one little corner of chemistry "two hundred millions" of complex compounds, bearing such names as chlorhydrobromhydrine, bromhydrodichlorhydrine, chlorhydrodibromhydrine, acetochlorhydrobromhydrine, and dibutyrosulphurine, and having these names *explained* by such awkward squads of symbols as constitute the "unitary" formulæ, which I have quoted on page 389, heaven help the future student of chemistry, and give him a longer life and a better memory than is allotted to mortal man in these days!

If the discovery of these compounds throws so extraordinary a flood of light over the constitution of glycerine, why is it that MM. Berthelot and De Luca have not dissected their unitary formulæ into rational formulæ? If that dissection is neglected while chemists are enlightened by this flood of light, how is it ever to be effected afterwards? Why have these gentlemen not favoured us with an interpretation of the formulæ $C^{10}H^{8}ClBrO^{4}$, which is assigned to the compound called Acetochlorhydrobromhydrine, and of which compound it is said, that "it contains at the same time glycerine, chlorhydric acid, bromhydric acid, and acetic acid, and is the first compound ever prepared, in which three different acids are combined with a single equivalent of glycerine?"

As the authors have not answered that question, I will answer it. Acetochlorhydrobromhydrine does not contain glycerine, it does not contain chlorhydric acid, it does not contain bromhydric acid, it does not contain acetic acid; and yet it is said to contain all four. Here we come upon a question of FACT, and that question must be settled before we have any talk about *theories*. The authors take four hydrated acids, which acids have among them six replaceable atoms of hydrogen, which hydrogen is indispensable to the completion of the acids, *as acids*, and cannot be separated from them without terminating their existence, *as acids*. The authors separate from these four acids all the six atoms of hydrogen, in company with three atoms of oxygen belonging to the acetic and the glyceric acids, and they then combine together the residues of the four acids left by the abstraction of these nine essential atoms, and having done that, they affirm that this compound of the four residues contains in fact all the four acids with which they commenced operations.

This method of philosophising reminds me of a joke to be found in the pages of our old friend Joe Miller. You take, according to his recommendation, the word "majesty." You abstract the two ends of it, and having thus produced the residue, "a jest," you insist that this residue is still "majesty," only minus its externals. In like manner, our authors, in the present case, take the formula HCl, which represents hydrocloric acid; they remove H and leave Cl, and then they insist that the residue, Cl, is still hydrochloric acid, having only undergone the trifling abstraction of its external hydrogen. The blunder which is committed by these gentlemen is that of treating the NEGATIVE RADICALS of acids as if they were the SAME THINGS as the ACIDS IN A STATE OF COMPLETENESS, and the blunder is one that vitiates the whole train of their reasoning. In acetochlorhydrobromhydrine, instead of having the four complete acids which are stated to be its constituents, we have only the radical C^3H^5, the radical C^2H^3, the radical Cl, and the radical Br, with two remaining atoms of oxygen. The simplest rational formula for a compound containing only these residues is,

$$C^3H^5,BrO + C^2H^3,ClO;$$

according to which formula the compound is a combination of oxychloride of acetyl with oxybromide of glycyl, and it contains not one of the four acids which we are desired to believe to be collectively contained in it. To offer such a compound as this, as evidence of the truth of the theory, that *glycerine is a teratomic alcohol, which can combine at once with three different acids*, is to suppose that we have lost the power to observe facts, and the right to judge of their relations. If scientific academicians admit such theories as this, proved by such evidence, to be true philosophy, they ought to be punished by being made to commit to memory the two hundred millions of hard words, which MM. Berthelot and De Luca threaten to inflict upon us.

But, now, let it be understood, that I am making no objections to the experiments and discoveries of these gentlemen, which are really valuable. I object only to the ridiculous theory of polyatomic alcohols, by which the interpretation of their results is caricatured. When the new compounds are stripped of these dainty devices, we perceive their value and utility.

Here follows a different interpretation of the 20 compounds described in the above Table. Several of them have been already inserted at pages 374, 375, namely, at Nos. 36, 6, 34, 35, 14, 38, and 26, in the list there printed; but I repeat them here, to facilitate the comparative view of the formulæ and nomenclature of the whole set of compounds, according to the two systems.

1.	$H,C^3H^5O^2 + HCl$	Hydra glycylete cum hydra chlora.
2.	$H,C^3H^5O^2 + HBr$	Hydra glycylete cum hydra broma.
3.	$H,H,C^2H^3; C^3H^5O^4$	Hydren acetyla glycylote.
4.	$C^3H^5,ClO + HCl$	Glycyla chlorate cum hydra chlora.
5.	$C^3H^5,BrO + HBr$	Glycyla bromate cum hydra broma.
6.	$C^3H^5,BrO + HCl$	Glycyla bromate cum hydra chlora.
7.	$H,(C^2H^3)^2; C^3H^5O^5$	Hydra acetylen glycylute.
8.	$H,C^3H^5O^2 + C^2H^4,ClO$.	Hydra glycylete cum acetyla chlorate.
9.	$H,C^3H^5O^2 + C^2H^3,BrO$	Hydra glycylete cum acetyla bromate.
10.	$C^3H^4Cl,Cl + HCl$	Chloric-glycyla chlora cum hydra chlora.
11.	$C^3H^4Br,Br + HBr$	Bromic-glycyla broma cum hydra broma.
12.	$C^3H^4Br,Cl + HCl$	Bromic-glycyla chlora cum hydra chlora.
13.	$C^3H^4Br,Cl + HBr$	Bromic-glycyla chlora cum hydra broma.
14.	$(C^2H^3)^3; C^3H^5O^6$	Acetyline glycylaze.

15. $C^3H^5,ClO + C^2H^3,C^2H^3O^2$ Glycyla chlorate cum acetyla acetylite.
16. $C^3H^5,BrO + C^2H^3,C^2H^3O^2$ Glycyla bromate cum acetyla acetylite.
17. $C^3H^5,ClO + C^2H^3,ClO$. Glycyla chlorate cum acetyla chlorate.
18. $C^3H^5,BrO + C^2H^3,BrO$ Glycyla bromate cum acetyla bromate.
19. $C^3H^5,BrO + C^2H^3,ClO$ Glycyla bromate cum acetyla chlorate.

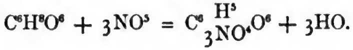
20. $C^3H^5,SO^3 + C^4H^7,C^4H^7O^2$ Glycyla sulphite cum butyryla butyrylite.

[In this Table $H = 1$, $C = 12$, $O = 16$.]

These formulæ do not exhibit the slightest trace of the existence of a teratomic alcohol; but, on the other hand, the cloud of smoke produced by the unitary formulæ being cleared away, we perceive that the compounds are all double salts of very definite and intelligible constitution. I need not repeat the arguments that have been already urged, but will confine myself to a few explanatory notices. Nos. 1 and 2 are compounds of monobasic glycylic acid with hydrogen acids. I might with much safety declare that glycylic acid is allylic acid; for these compounds go far to prove that allyl and glycyl are identic. Nos. 3, 7, and 14, are the three acetines, which have been fully discussed at Nos. 6, 14, and 26 of the former series. 4, 5, and 6, are compounds of oxychloride and oxybromide of glycyl with hydrogen acids. 8 and 9 are compounds of monobasic glycylic acid with oxychloride and oxybromide of acetyl. 10, 11, 12, 13 are bichlorides, bibromides, &c. of chloric-glycyl and bromic-glycyl, that is to say, of glycyl in which H^1 has been replaced by Cl^1 or Br^1. This vice-radical is analogous in its constitution to the bromic-phenyl and chloric-phenyl, which occur in the aniline series. See page 276. 15 and 16 are compounds of oxychloride and oxybromide of glycyl with anhydrous acetic acid. 17, 18, and 19, are all pairs of compounds of oxychloride and oxybromide of acetyl, with oxychloride and oxybromide of glycyl. No. 20 represents a double anhydride, each containing two acid radicals and consequently three atoms of oxygen. It will be seen, that the theoretical views which I have explained, give a reason for the quantity of oxygen which is present in each compound, and for its allotment to special salts. According to the unitary system, the quantity of oxygen which *remains* in each compound is simply what the hydrogen *did not require* for its conversion into water; but, according to my view, the oxygen that remains is that which is demanded by the number and the chemical powers of the residual radicals.

If the chemical quaternions which appear in the above list were really, as MM. Berthelot and De Luca describe them, *quadruple hydrated acids*, it would be indeed a marvellous thing that so many of them should be perfectly neutral. But when we perceive that these neutral compounds are anhydrides, and reflect that even the sulphuric anhydride is neutral, the wonder ceases; and we perceive that the removal from the compounds of the basic hydrogen is the removal of the chemical power, by means of which the acidity of the hydrated acid was made manifest. Hence it is consistent with all analogies, that such compounds as Nos. 15 to 20, each formed by four acids, should, after abandoning 3HHO, become perfectly neutral. Let it be remembered, however, that these compounds, though *formed* by four acids, do not *contain* four acids.

NITRO-GLYCERINE.—A note by Professor Williamson on this compound appears in the Proceedings of the Royal Society for June 15, 1854. By acting on glycerine with a mixture of nitric and sulphuric acid, he produced a compound of the following constitution:



$$C^6H^8O^6 + 3NO^5 = C^6\overset{H^5}{\underset{3NO^4}{}}O^6 + 3HO.$$

He considers that 3H in glycerine are replaced by $3NO^4$. On boiling this compound with a concentrated solution of potash, it produced glycerine and nitrate of potash. See Railton's Nitroglycerine, No. 43, page 385, with which Williamson's nitroglycerine is identic.

Hence it appears that Professor Williamson was on the point of discovering in 1854 those relations of glycerine to acids, which Berthelot and De Luca have been engaged in determining since that period.

At Nos. 42 and 43, I have formulated nitroglycerine as if it contained a zotic vice-radical, which is the view that best accords with the commonly-received opinion of its constitution; but the recent experiments of MM. Berthelot and De Luca point, I think, to conclusions that are more accurate, and which may be expressed as follows:

No. 42, De Vrij's Nitroglycerine:

$$= \left\{\begin{matrix} C^6H^5,NO^4 \\ H\ ,NO^3 \end{matrix}\right\} = \text{Glycyla nitrote cum hydra nitrite.}$$

No. 43, Williamson and Railton's Nitroglycerine:

$$= \left\{\begin{matrix} C^6H^5,NO^4 \\ N\ ,NO^5 \end{matrix}\right\} = \text{Glycyla nitrote cum nitra nitrute.}$$

Hence No. 42 is, in Berthelot's language, Binitrine, and No. 43 is Ternitrine. We have yet to find Mononitrine, the formula of which will be, $H,C^6H^5O^2 + H,NO^3$. Expressed synoptically, these three salts are:

Mononitrine = H,H,N ; $C^6H^5O^5$.
Binitrine = H,N,N ; $C^6H^5O^7$.
Ternitrine = N,N,N ; $C^6H^5O^9$.

Theory of Polybasic and Conjugated Acids.

Chemists have divided the salts of organic acids into three classes, which are said to contain one, two, or three equivalents of base combined with one equivalent of acid. This classification is so simple as to seem clear of all difficulties; but when we examine the facts, we find that the distribution of salts into these three classes is impracticable. Gerhardt and other chemists have, it is true, provided their disciples with abundance of rules for discriminating these different classes of acids from one another. But Gmelin—that master-spirit among systematic chemists—while explaining and illustrating these rules, nullifies them all in one short condemning sentence. "It is difficult," he says, "to decide with any degree of certainty" [*with any degree of certainty!*] "whether the formula of an acid should be so written as to make the acid monobasic, or twice as great so as to make it bibasic, or three times as great, so as to make it terbasic."—(*Handbook of Chemistry*, 1852, vii. 198.)

The law of simplicity, which nature always obeys, exacts from philosophers the simplest possible interpretation of every phenomenon. If a chemical fact can be explained by reference to *two* chemical atoms, it is a violation of the law of simplicity to explain it by reference to *four* or to *six* atoms; and this violation of a fundamental law ought not to occur unless enforced by overpowering facts. If it is possible to explain the constitution of salts by reference to monobasic acids, it is wrong to resort to bibasic acids or to terbasic acids, or to any other irregular or complex form of combination. The existence of such irregular compounds ought only to be admitted when proved by stringent evidence.

But, according to Gmelin, many of these polybasic acids are supported by no evidence whatever. They are not facts in chemistry, but contrivances in arithmetic. You make a monobasic acid into a bibasic acid by doubling its formula. You make it into a terbasic acid by tripling its formula. And "it is difficult to decide with any degree of certainty" whether the effects produced by this multiplication are right or wrong.

There can, at any rate, be little difficulty in deciding, whether the practice of such manœuvres is right or wrong. The law of simplicity forbids it. The doubling and tripling of formulæ, when not commanded by facts, and when resorted to for the purpose of bolstering up theories that are supported by no other evidence, is a trick which men of science should scorn.

If it is "difficult to decide *with any degree of certainty*," whether an acid with a doubled or tripled formula is really bibasic or terbasic, no benefit can be derived from the acceptance as realities of compounds so purely hypothetical; for, after we have manufactured them, we cannot safely use them, being placed in the unscientific predicament of floundering amidst uncertainties. If acids are truly polybasic, plain facts will be forthcoming to prove it. If polybasic acids are phantoms, undiscoverable in nature, unsupported by experiment, and resulting only from the duplication or triplication of the formulæ of monobasic acids, the recognition of such things as scientific facts, is a mockery of scientific exactness.

Let us examine these so-called polybasic acids with a determination to find out what they really *are*. We resolve beforehand not to be deceived by the masquerading habits in which mobs of atoms may be attired, to play the part of daws in borrowed plumes. When we come upon a terbasic acid whose status seems to depend upon a formula written " three times as great " as that of a monobasic acid, or upon a bibasic acid whose letters of recommendation are " twice as great " as those of a monobasic acid, we will examine, whether these pretentious bodies are actually polybasic acids, or only things that are made to appear like polybasic acids by the force of cumulative symbols; we will ascertain whether they are objects in nature, or contrivances of art; whether they have been discovered in the laboratory, or invented at the writing-desk. In other words, we will endeavour to determine whether there really exist such compounds as polybasic acids, or whether all acids are not invariably and absolutely monobasic. The theory of the constitution of salts ought not to remain in the state of dreary doubtfulness in which Gmelin represents it to be. Chemists must either *prove* that polybasic acids ARE *polybasic*—absolutely and unquestionably polybasic, and not polybasic by convention upon the strength of "trimmed" formulæ—or they must cease to use a term which, on the failure of such proof, must be held to countenance an illusion.

For my part, I reject the commonly-received doctrines respecting polybasic acids *in toto*, and I hope to be able to prove to the reader that those doctrines are unworthy of credit. A salt, as I understand that term, is a compound of two radicals, which may be either simple or compound, oxidised or not oxidised, but each of which radicals must be equivalent to one volume or one atom of hydrogen. I do not admit that one acid radical can combine directly with two or with three basic radicals, nor that one basic radical can combine directly with two or with three acid radicals. The saturating capacity of a radical never changes. It is always equal to the equivalent of one volume of hydrogen. I admit, nevertheless, that salts exist which contain unequal numbers of basic and acid radicals, and I explain that fact by the following hypothesis:

Let B = any Basic radical.
A = any Acid radical.

The formula B + A represents most of the salts with which we are acquainted, such as the sulphates, the oxalates, the acetates, the benzoates, and other normal salts of monobasic acids. I make it here a question of the combination of two radicals, leaving the oxygen, both as regards its quantity and its distribution, entirely out of consideration.

The normal salt B + A, I consider to be able to act as a basic radical against A, and as an acid radical against B. Hence B + A can combine with the radical B, and produce the compound salt BA + B. In this manner the carbonates are produced. See page 183. These salts are bibasic and monacid. In the same way, the normal salt B + A can combine with the radical A, and produce the compound salt A + BA. In this manner we obtain the hyposulphates. See page 172. These salts are monobasic and biacid. Thus, we have a clear distribution of salts into three classes:

Bibasic and monacid = B,BA.
Normal = BA.
Monobasic and biacid = BA,A.

These three classes of salts are distinguishable by analysis, and present no uncertainties. The cloud which everlastingly envelops the compounds of "acids and bases," disappears when you look at the salts through the medium of the radical theory. You then perceive the true nature of double salts, not only of those which are biacid and bibasic in the sense which I have just explained, but of these which are at the same time bibasic and biacid, or which are double salts in the ordinary sense of that term; such as the sulphites, the bisulphates, and the phosphates. In the preceding pages, I have thoroughly investigated the constitution of these several classes of salts; and in the article on the phosphates, I have especially shown in what manner the acids that are commonly called bibasic and terbasic, may be reconciled with the theory which admits of none but monobasic acids, or, to speak more accurately, with the theory which assumes that every radical has, under all circumstances, the saturating capacity of a single volume of hydrogen—a chemical power which nothing can increase nor diminish.

Undoubtedly, the bibasic phosphates contain *two* basic radicals, and the terbasic phosphates contain *three* basic radicals, to each *single* acid radical, provided you narrow the meaning of the term *acid radical* so as to make it include only the phosphorus of these salts. But I am for giving to the term *acid radical* a wider signification. The radicals which occur in the phosphates, exclusive of phosphorus, are hydrogen, metals, and hydrocarbons. None of these radicals are necessarily incompetent to act the part of acid radicals. I have shown that hydrogen, under the force of one set of circumstances, can act as an acid radical just as decidedly as, under the force of another set of circumstances, it can act as a basic radical. In water—if the formula H + HO is accepted as its model—hydrogen acts both as a basic radical and as an acid radical; and in the consequences which flow from the adoption of this model, we have ample evidence of the fact, that what we call basicity and acidity are qualities that are relative and not absolute; so that either of them may be justly applied to the same radical placed under the action of different chemical forces. Thus, in hydrate of lime = $Ca + HO$, the calcium is a basic radical, while in quicklime = $Ca + CaO$, the oxidised atom of calcium is in the condition of an acid radical. If $Ca + CaO$ comes into reaction with $H + HO$, double decomposition occurs, and the basicity and acidity of the four radicals are so changed, that both the atoms of Ca become basic, and both the atoms of H become acid:

$$Ca,CaO + H,HO = Ca,HO + Ca,HO.$$

This hypothesis is in accordance with the electro-chemical theory, and commands all the support which that theory can give it.

According to this method of viewing the relationships of radicals, the salts that are called terbasic phosphates and bibasic phosphates, are not to be considered as compounds respectively of three atoms of base and two atoms of base with one atom of acid, but as double and triple salts in which the number of basic radicals and acid radicals is in all cases the same. Thus:

$KO + POO$	The monobasic phosphate, a single normal salt.
$\left\{\begin{matrix} KO + POO \\ K + KO \end{matrix}\right\}$	The terbasic phosphate, a double salt, containing a monobasic phosphate and a salt on the model of water.
$\left\{\begin{matrix} \left\{\begin{matrix} KO + POO \\ K + KO \end{matrix}\right\} \\ KO + POO \end{matrix}\right\}$	The bibasic phosphate, a triple salt, containing both the above varieties.

I have entered so fully into details respecting the constitution of the Phosphates, in the article given at page 138, that I need only to refer to that article for farther explanations, and for evidence of the facts. The conclusion to which I wish to bring the reader's attention is, that if, as I assume, the phosphates are multiple salts, built up of normal monobasic salts, they lend no support to the commonly-received doctrines respecting the constitution of polybasic organic acids; so that, when we come to examine the constitution of organic acids, we are not to be led astray by the intimation that this acid is terbasic, and that that acid is bibasic, because their salts agree in form with the terbasic and the bibasic phosphates, but we are to insist that every acid which claims to be terbasic or bibasic shall individually supply evidence to justify its particular claim. If we pursue that course, I expect that we shall end our inquiry by proving that *the theory of Polybasic Acids is a* FALLACY.

Before I proceed to the critical analysis of bibasic and terbasic acids, I must trouble the reader with a glance at the theory of conjugated acids; for I find it to be impossible to keep the details respecting polybasic acids and conjugated acids from intermixture.

Bisulphates of Alcohol Radicals.

The positive or basic radicals of the vinyl series combine with sulphur and oxygen to form a variety of salts,—sulphates, sulphites, &c. In each of these salts, that quantity of the compound radical which is equivalent to one volume of hydrogen, replaces one atom of hydrogen of the hydrated acid, and produces a neutral salt; such as—

$$C\,H^3,SO^2 = \text{Sulphate of methyl.}$$

$$C^5H^{11},SO^2 = \text{Sulphate of amyl.}$$

$$\left.\begin{matrix} C^2H^5,C^2H^5;\ S^2O^3 \\ = C^2H^5,SO + C^2H^5,SO^2 \end{matrix}\right\} = \text{Sulphite of ethyl.}$$

When these salts are gaseous, their atomic measure is the same as that of their positive radicals, because neither sulphur nor oxygen exhibits any measure in gaseous salts.

These neutral sulphates and sulphites of alcohol radicals have the property of forming double or acid salts by combining with an equivalent of hydrated acid. Thus we obtain such compounds as the following:

$$\left.\begin{matrix} CH^3,SO^2 + H,SO^2 \\ = H;\ CH^3;\ (SO^2)^2 \end{matrix}\right\} = \text{Bisulphate of methyl.}$$

$$\left.\begin{matrix} C^5H^{11},SO^2 + H,SO^2 \\ = H;\ C^5H^{11};\ (SO^2)^2 \end{matrix}\right\} = \text{Bisulphate of amyl.}$$

$$\left.\begin{matrix} H;\ C^2H^5;\ S^2O^3 \\ = C^2H^5,SO + H,SO^2 \end{matrix}\right\} = \text{Bisulphite of ethyl.}$$

In all of these salts, the atom of H is replaceable by any other basic radical, simple or compound; by which replacement it is possible to produce a great variety of salts, in accordance with the above formulæ.

This is my view of the constitution of this class of double salts; but the view which is commonly accepted by chemists is entirely different, and it is into the investigation of the propriety of this different view, that I have to request the reader to follow me.

According to the common opinion, the oxidised sulphur contained in one of these salts is directly combined with its oxidised organic radical, into a "*Conjugated*" "*Copulated*" "*Coupled*" or "*Colligated*" ACID, which acid produces salts by combining with HO or MO, considered a a BASE. Now, I deny that there is any evidence to prove the formation of such Conjugated Acids, or that the organic radical ever acts otherwise in these salts than as a basic radical, neutralising one-half of the oxidised sulphur, or that proportion whose hydrogen it replaces, and leaving free for action the other half of the oxidised sulphur, whose hydrogen it has not replaced, and whose saturating capacity it has not nullified. The problem for determination, therefore, is, whether the alcohol radicals which are present in these salts, act as *basic radicals*, or as *ingredients in conjugated acid radicals*. I shall confine the discussion at present to the bisulphates, leaving the investigation of other sulphur salts to other sections.

The following formulæ are written according to my notation and atomic weights:

$$C^2H^5,SO^2 + H,SO^2 = H ; C^2H^5 ; (SO^2)^2.$$
$$C^2H^5,SO^2 + K,SO^2 = K ; C^2H^5 ; (SO^2)^2.$$

The first of these salts is the double sulphate of ethyl and hydrogen. It is commonly called the sulphovinic acid. The second salt is the double sulphate of ethyl and potassium. It is commonly called the sulphovinate of potash. Their names according to the new nomenclature are as follow:

$H ; C^2H^5 ; (SO^2)^2$ = Hydra ethyla bisulphete.
$K ; C^2H^5 ; (SO^2)^2$ = Potassa ethyla bisulphete.

In organic chemistry, we find a multitude of sulphates of this description, each of which contains ethyl or some other basic radical of the vinyl series, and in all of them the basic H or K, is replaceable by any other metal or basic radical, producing an extensive series of double sulphates, agreeing exactly in composition with the double sulphates of the inorganic kingdom. See page 150. But organic chemists are not content to consider the sulphovinates as double sulphates. That would be in effect the accommodation of organic chemistry to the rules of inorganic chemistry, whereas it appears to be an article of faith with the professors of organic chemistry that, before all things, it is necessary to cut an impassable trench between the two departments of the science, and so prevent their intermixture. Hence the "conjugated sulphates" are removed from the domain of inorganic chemistry; each of them is assumed to be something different from an ordinary bisulphate, and is raised to the dignity of a special acid, and made the heading of a new chapter in every book on organic chemistry. From this notion arise the sulphovinic acid, the sulphomethylic acid, the sulphamylic acid, the sulphophenylic acid, the sulphethalic acid, and scores of others; all of them prolific sources of troublesome, puzzling, worthless synonymes, which encumber the books, load the memory, and hinder the progress of the science which their advocates sarcastically make pretensions to advance.

What is gained by the subdivision of chemical compounds into innumerable petty families, founded upon distinctions without differences, and which is so common among these conjugated acids? What is the gain, beyond perplexity and time-wasting? The excuses commonly made for this practice are scarcely worthy of serious discussion. In regard to the sulphovinates, the excuse is, that a solution of this acid gives no precipitate with a solution of barytes, and therefore it cannot be a solution of a sulphate. The fact does not warrant the conclusion. What the sulphovinic acid could produce by double decomposition with a salt of barytes, is, *the double sulphate of barytes and ethyl*, which is a soluble salt and consequently not precipitable. To conclude, from the non-precipitation of this salt, that no sulphates are present, is to set all knowledge of the properties of double salts at absolute defiance. This is not reasoning; this is not chemical science; it is only a fashion with organic chemists.

But this excuse is bad for another reason. The action of inorganic reagents upon the radicals of inorganic acids in the presence of organic radicals, is almost always different from the action which they exercise when none but inorganic radicals are present. This is the case not only when the inorganic acids are combined with basic organic radicals, but also when acid organic radicals, and even neutral organic compounds, such as sugar, are present in the solution. The action of the reagents is different, because they are applied under different circumstances. There is a strong tendency in all organic radicals to produce compound soluble salts—with one another, and with inorganic radicals. This complicates the action of the reagents, and it is consequently rash in the highest degree to declare that a solution contains no sulphuric acid, merely because it gives no precipitate with a solution of barytes in the known presence of organic radicals.

The absurdity of setting forth these double sulphates as conjugated acids is best seen if we compare one of them with a double salt of similar constitution, but having an inorganic positive radical:

$$C^2H^5,SO^2 + HSO^2 = \text{Bisulphate of ethyl.}$$
$$K,SO^2 + HSO^2 = \text{Bisulphate of potash.}$$

These two compounds are equivalent, atom for atom. The theory of conjugated acids supposes that, in the bisulphate of ethyl, only the single atom of hydrogen is basic, and that all the other constituents of the compound become conglomerated into an acid radical, which produces the conjugated acid:

$$H + C^2H^5,SO^2,SO^2 = \text{Ethylo-sulphuric acid.}$$

The same transformation, performed on the inorganic bisulphate, would produce a similar conjugated acid:

$$H + K,SO^3,SO^3 = \text{Potassio-sulphuric acid.}$$

And this conjugated acid, like the former, actually produces a whole series of salts, such as

$Mg + K,SO^3,SO^3$.	Potassio-sulphate of magnesia.
$G + K,SO^3,SO^3$.	Potassio-sulphate of glucina.
$C^4H^5 + K,SO^3,SO^3$.	Potassio-sulphate of ethyl.

The potassio-sulphuric acid is moreover completely justified by M. Gerhardt's law for determining the basicity of conjugated acids. That law says, that if you add together the basicity of all the elements of a conjugated acid, and deduct 1 from the sum, the residue is the basicity of the conjugated acid. Now if we add, as he instructs us, 2 for the two atoms of sulphuric acid to 0 for the potassium, and deduct 1, we have a residue of 1, which is, true enough, the basicity of the bisulphate of potash. You can, to be sure, by looking at the formula of bisulphate of potash, and observing that it contains just 1 atom of basic hydrogen, come to the same conclusion without a law and without a reckoning, but that is too empirical a mode of procedure to please organic chemists, whose awful gravity is best pleased with obscure laws and profound complexity.

I have elsewhere stated, but I may repeat the statement here as apropos to the occasion, that Gerhardt's law for determining the basicity of a conjugated acid is erroneous. If the saturating capacity of each acid radical of the compound be reckoned as *unity*, or 1, it is absurd to reckon the saturating capacity of the basic radical which is presumed to be acting as part of the acid radical as *null*, or 0. It ought to be reckoned as a *minus* quantity, viz., —1. It is this blunder which makes Gerhardt declare that the basicity of a conjugated acid is always less by unity than the collective basicity of its constituents. But the saturating capacity of a radical can neither be lost nor lessened. The quantity 1 cannot become 0, except by neutralisation with the quantity —1.

Chemists of the old school will perhaps say, that it is absurd to convert bisulphate of potash into an acid, and to make potassium form part of a compound acid radical, and I grant that it is absurd; but I am showing that the acknowledged laws for constructing conjugated acids and for determining their basicity, require no straining to make them warrant that procedure. If, therefore, chemists of the old school forbid the construction of

$$C^4H^5; K,S^2O^6 = \text{the Potassio-sulphate of ethyl,}$$

let them also forbid the construction of

$$K; C^4H^5,S^2O^6 = \text{the Ethylo-sulphate of potash,}$$

for the latter is quite as extravagant as the former, and there is no more reasonable excuse for making a compound acid radical with ethyl than for making one with potassium.

These conjugated acids and their salts are elaborately described in the chemical systems of Gmelin and Gerhardt, yet the latter, in the concluding part of his work, has declared that the sulphovinic acid is a bibasic sulphate, and that acids of that class are not to be considered as "conjugated." But the age of knight-errantry has not entirely passed away, and when one doughty champion abandons his lady-love, another appears ready to rescue her from destruction. So, just as Gerhardt retires from the lists, Dr. Guthrie stands forward as the champion of the conjugated acids, and publishes a Paper to prove that the prevalent views respecting them are correct. As I entirely dissent from his conclusions, I shall quote and examine his experiments and arguments.[1]

"With respect to the rational constitution of the sulphovinates, chemists are at present so far agreed as to admit in them the presence of sulphuric acid. An objection was formerly raised to this view, on the ground that the sulphuric acid could not be shown to exist, as such, by means of the usual reagents; and it was assumed that the salts in question contained hyposulphuric acid. This position has, however, been overthrown, partly by the discovery of isethionic acid, partly by the observed behaviour of other compounds of ethyl, such as the chloride and sulphide of ethyl, in which the chlorine and sulphur are much more difficult to recognise by means of nitrate of silver, than is the case with the soluble inorganic compounds of these bodies.

"A question, however, which still has to be answered, is—'In what *manner* do the sulphovinates contain the sulphuric acid?'

"Those chemists who look upon sulphuric acid as a bibasic acid, and express the composition of its hydrate by the formula $2HO,S^2O^6$, view, for the most part, the salts of sulphovinic acid as basic sulphates, one of whose atoms of base is potash, and the other oxide of ethyl. They accordingly class sulphovinate of potash with the so-called double salts of sulphuric acid, such as the potassio-sulphate of zinc.

$$\left.\begin{matrix}ZnO\\KO\end{matrix}\right\}S^2O^6\text{, Sulphate of potash and zinc.}$$

$$\left.\begin{matrix}C^4H^5O\\KO\end{matrix}\right\}S^2O^6\text{, Sulphate of potash and ethyl.}$$

"Now, in the first place this view is contradicted by the fact that the oxyde of ethyl in the second of these salts cannot be driven out by a more powerful base, as is the case with its analogue, the oxide of zinc, in the inorganic sulphate. Even on continued boiling with potash, the ether is not given off as alcohol. The difficulty of maintaining this view, again, is materially increased when we reflect that in the

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[1] On the Sulphovinates, and on Amylophosphoric Acid and the Amylophosphates. By F. Guthrie, B.A, Ph. D., *Quarterly Journal of the Chemical Society* (1856), IX. 131.

$$\text{Neutral sulphate of ether, } \left.\begin{array}{l} C^4H^5O \\ C^4H^5O \end{array}\right\} . S^2O^6,$$

the one atom of ether may be eliminated or exchanged for water, or a base, much more easily than the other; and that the so-called neutral ethers, such as acetic, nitric, or oxalic ether, on being boiled with caustic potash, are transformed under formation of alcohol, into the potash salts of the corresponding acids.[1]

"These considerations render it more than doubtful whether the metallic oxide and the oxide of ethyl be equally basic in function. It seemed desirable, that new facts should be gained for the elucidation of this point. I imagined that such facts might be furnished by the behaviour of an aqueous solution of the sulphovinate towards the galvanic current. For if, in the sulphovinate of potash, both the potash and ether be united as base with the sulphuric acid, we should be justified in expecting, on electrolysing a concentrated aqueous solution of this salt, that, at the + pole, sulphuric acid and oxygen would be liberated, and, at the − pole, potassium (potash and hydrogen), together with ethyl (or ether or some ethyl compound, possibly hydride of ethyl).

"Into a cold, concentrated, aqueous solution of sulphovinate of potash, free from sulphate of potash, I accordingly introduced two platinum electrodes, in such manner that they were separated by a porous clay cell. The electric current from four Bunsen's carbo-zinc elements was sufficient to effect a lively disengagement of gas at both poles, accompanied by an evolution of heat which rendered cooling from the exterior necessary. In a short time the liquid surrounding the + pole showed a strong acid reaction. The gas which was here liberated smelt distinctly of aldehyde, and consisted of oxygen and carbonic acid. The liquid at this pole gave, with chloride of barium, a white precipitate which was insoluble in hydrocloric acid. Sulphuric acid was therefore present in the free state. At the same time, the liquid at the − pole assumed an alkaline reaction, and the gas there liberated proved to be pure hydrogen. I satisfied myself, by careful examination, of the entire absence of all carboniferous gases, nor could I detect at this pole the slightest traces of ether or alcohol.

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[1] These arguments proceed on the unwarranted assumption, that the properties of organic sulphates ought to be the same as the properties of the inorganic sulphates. We might as reasonably argue, that the inorganic sulphates ought all to have uniform properties, and that sulphate of magnesia cannot be a sulphate because it is not insoluble, like sulphate of barytes.—J. J. G.

"It was imagined that the sulphuric acid and the aldehyde, which appeared at the + pole, might be secondary products of decomposition, effected by the oxygen, *in statu nascenti.* To get rid of this secondary decomposition, I formed the + pole of amalgamated zinc. On completing the circuit, a lively disengagement of gas took place at the − pole, as before, while, on the other hand, at the + pole, no gas at all was liberated, and neither aldehyde nor sulphuric acid were formed. The zinc electrode, however, soon became covered with a pellicle of sulphovinate of zinc, which, after a time, broke the electric current. Again, a fresh solution being taken, the liquid at the + pole was made strongly alkaline with carbonate of potash. On the introduction of platinum electrodes, carbonic acid was plentifully liberated at the + pole, but as no sulphate of potash could be detected, it followed that this was due to the liberation not of sulphuric, but of sulphovinic acid.

"In the same manner, making use of platinum electrodes, I electrolysed an aqueous solution of amylosulphate of potash, and recognised precisely analogous phenomena. At the + pole, oxygen was liberated, and a distinct smell of valerianic acid noticeable. The solution around this pole became acid, and contained sulphuric acid. At the − pole the liquid became distinctly alkaline, and the gas there liberated was, as before, pure hydrogen. The slightest traces of fusel oil or amylic ether would at once have been recognised, by their powerful odour, had they been separated. The liquid at the − pole remained inodorous.

"From these experiments I believe the conclusion may legitimately be drawn, that in amylosulphate and sulphovinate of potash, the oxides of ethyl and amyl have not the same function as the potash, but they are combined with the sulphuric acid in a different, and, as it appears, a more intimate manner. The fact that, on electrolysis, these organic oxides remain with the sulphuric acid, and accompany it to the + pole, shows that the potash alone is the electro-positive constituent of these salts, and that the formula $\left.\begin{matrix}KO\\C^4H^5O\end{matrix}\right\}S^2O^6$ expresses a hypothesis on the constitution of sulphovinate of potash which rests upon false assumption.

"It seemed to me of importance to examine in a similar manner the ethylophosphates, and to see whether in these the organic oxide is liberated at the + pole, as in the sulphovinates, or whether it goes to the − pole. For this purpose, the amylophosphate of potash was chosen, because, if the oxide or hydrated oxide of amyl were liberated, together with the metallic oxide, at the − pole, it would be at once recognised by the mere odour. On introducing the platinum electrodes into a concentrated aqueous solution of amylophosphate of potash, separated into two portions by a clay cell, hydrogen was liberated at the − pole, and oxygen, together with carbonic acid at the + pole. The solution at the latter pole assumed an acid reaction, and smelt distinctly of valerianic or butyric acids (evidently secondary products of decomposition), the liquid at the − pole became alkaline but remained odourless.

"From this it would appear that in the amylophosphates, and, generally, in the ethylophosphates, we are not at liberty to assume that the organic oxides are combined in the same manner as the metallic oxides; that is, as base. Accordingly, we must not understand the ordinary formulæ for ethylo- and amylophosphate of potash

$$\left.\begin{matrix}2KO\\C^4H^5O\end{matrix}\right\}.PO^5, \text{ and } \left.\begin{matrix}2KO\\C^{10}H^{11}O\end{matrix}\right\}.PO^5,$$

as if the organic oxides played the same part in them as does the basic water in the ordinary tribasic phosphate of potash $\left.\begin{matrix}2KO\\HO\end{matrix}\right\}.PO^5$, but we must rather assume that the phosphoric acid, together with the oxide of amyl, forms a bibasic amylophosphoric acid."

With submission to Dr. Guthrie, I hold that the results of his experiments are entirely at variance with the conclusions which he is pleased to draw from them. He considers that "on electrolysis, *the organic oxides remain with the sulphuric acid, and accompany it to the + pole*, showing that the potash alone is the electro-positive constituent of the salts." But his experiments prove, that when ETHYL is operated upon, instead of going with the sulphuric acid to the + pole, it suffers decomposition into *hydrogen*, which goes to the − pole, and the acid radical *acetyl*, which goes in the form of aldehyd to the + pole:

$$\text{Ethyl} = C^4H^5 - H^2 = C^4H^3 \text{ Acetyl.}$$

So also the experiments prove that when amyl is operated upon, it does not go with the sulphuric acid to the + pole, but is decomposed into *hydrogen*, which goes to the − pole, and the acid radical *valeryl*, which goes to the + pole in the form of valerianic acid:

$$\text{Amyl} = C^{10}H^{11} - H^2 = C^{10}H^9 \text{ Valeryl.}$$

The result is the same in the presence both of sulphuric acid and phosphoric acid. Neither of these acids prevents the reduction of ethyl to acetyl, nor of amyl to valeryl, and Dr. Guthrie's assumptions that ethyl and amyl go to the + pole in combination with the strong acids, because he finds then acetyl and valeryl are consequently unwarranted, and at variance with his experiments. I have already drawn attention to the general fact, that compound radicals which contain one atom of hydrogen above the proportion contained in any multiple of the neuter radical vinyl (see page 76) are in most cases basic or positive radicals, but convertible into acid or negative radicals by the abstraction of *two atoms* of hydrogen. Dr. Guthrie's experiments confirm this general fact; they prove that ethyl is reducible to acetyl, and amyl to valeryl, that the abstracted hydrogen goes to the – pole, and that the two acid radicals, go, as they ought to go, to the + pole, with the sulphuric and phosphoric acids; but this is the very opposite from proving that ethyl and amyl are acid radicals, that they act as such in the sulphovinates and the amylophosphates, and that, when these salts are electrolysed, the radicals in question accompany the mineral acids to the + pole; and, therefore, I say that Dr. Guthrie's arguments are at variance with his experiments.

The electrolysis of the organic radicals, if we may judge from the experiments quoted at page 76, and from these new experiments made by Dr. Guthrie, appears to be subject to the following general conditions:

1). When negative radicals in the state of salts of potash are operated upon, the negative radicals lose carbon and become positive radicals. Thus valeryl becomes butyl, acetyl becomes methyl, caproyl becomes amyl, and œnanthyl becomes hexyl.

2). When positive radicals in the state of sulphates, phosphates, &c., are operated upon, they lose hydrogen and become negative radicals. Thus, ethyl becomes acetyl, and amyl becomes valeryl.

Dr. Guthrie's experiments have served to enlarge our knowledge of these particulars, and to strengthen the argument respecting the constitution of the conjugated sulphates; only he misunderstood his results, and drew his conclusions in favour of the wrong side of the argument.

The result of this investigation is to confirm the opinion with which I set out, and with which I trust the reader will now agree, namely, that all the sulphates which contain positive radicals of the vinyl series, in company with metallic radicals, are merely double salts. I find nowhere either experiments more decisive, or arguments more cogent, in support of the doctrine of conjugated acids (as distinct from double salts) than the arguments and experiments of Dr. Guthrie.

And this conclusion applies, not merely to the sulphates, but to the phosphates, sulphites, hyposulphates, carbonates, oxalates, and all similar "conjugated" salts. The whole of these I take to be double salts, in which simple salts of inorganic positive radicals are combined with simple salts of organic positive radicals; and I would recommend the dismissal from chemical science of the entire series of denominations of conjugated acids to which misunderstood experiments and fallacious arguments have given origin.

Professor Kolbe's Copulated Oxalates.

Professor Kolbe has advocated the doctrine, that the acid radicals of the vinyl series—see page 79—are all compounds of basic radicals with carbon, and, consequently, that all their salts are *oxalates copulated with basic radicals*, according to the following examples:—

$$\begin{array}{rcl} HO.(C^2H^3)\frown C^2,O^3 & = & \text{Acetic acid.} \\ KO.(C^2H^3)\frown C^2,O^3 & = & \text{Acetate of potash.} \\ (C^4H^5)O.(C^2H^3)\frown C^2,O^3 & = & \text{Acetate of ethyl.} \\ HO.\quad H\ \frown C^2,O^3 & = & \text{Formic acid.} \\ HO.(C^8H^9)\frown C^2,O^3 & = & \text{Valeric acid.} \end{array}$$

In these formulæ $C = 6$, $O = 8$, $H = 1$.

This theory is advocated at great length in the *Quarterly Journal of the Chemical Society*, vols. iii. and iv.

According to this doctrine, we are to believe that every neutral salt of an organic acid is an oxalate possessing a sort of appendage or tail, which is copulated with it without affecting its neutrality, although in every instance the tail is a complete basic radical. Thus, a formiate is an oxalate with a tail of hydrogen; an acetate is an oxalate with a tail of methyl; a valerianate is an oxalate with a tail of butyl; and so on through the entire vinyl series of acid radicals. The proof of the correctness of this doctrine consists of the single fact, that these acids can be decomposed, electrically and otherwise, into carbon and their corresponding basic radicals. I admit the fact. See pages 75 and 76. But I consider the doctrine thus based upon the fact to be absurd, and in order to prove its absurdity, I will carry it to its legitimate consequences.

For the sake of the argument, I admit that the acid radicals of the vinyl series are each reducible into an atom of carbon and an atom of a basic radical. I have discussed this matter fully between pages 73 and 81. Thus, an acetate can produce methyl and a valerianate can produce butyl. "Right!" says Kolbe, "and therefore the acetates contain methyl, and the valerianates contain butyl."

Just, however, as every acid radical of the vinyl series can be made to produce a basic radical by abstraction of C^1, so can every basic radical of that series be made to produce an acid radical by abstraction of H^2; and if we are to consider that every acid radical *contains* a basic radical, we may with equal reason assume that every basic radical *contains* an acid radical, and when we depict the acetate of potash as containing an oxalate copulated with methyl, we may depict the sulphate of ethyl, as containing hydrated sulphuric acid copulated with hydride of acetyl. Stated in my notation, these changes would be as follow:

$$\begin{array}{cccc} K,C^2H^3O^2 & = K,CO^2 & + & CH^3 \\ \text{Acetate of potash} & = \text{Oxalate of potash} & + & \text{Methyl.} \end{array}$$

$$\begin{array}{cccc} C^2H^5,SO^2 & = H,SO^2 & + & H,C^2H^3 \\ \text{Sulphate of ethyl} & = \text{Sulphuric acid} & + & \text{Hydride of acetyl.} \end{array}$$

The result is, that as, in all salts formed by an acid radical, we have, according to Kolbe, not the nominal acid radical, but practically the corresponding basic radical, so in all salts formed by a basic radical, we must have, not the nominal basic radical, but its corresponding acid radical. Everything falls out according to the rule of contrary: our acids contain bases, and our bases contain acids. In salts of acetyl we have only methyl. In salts of ethyl, we have only acetyl. And this principle of regularity extends through the whole series of radicals which are described in the Table on pages 79 and 80. The full force of the principle is felt, if we ask ourselves the question, What is the actual constitution of any given acid in that list? Take, for example, the valerianic acid, which is near the bottom of the Table. According to Kolbe, this acid *contains* butyl, not valeryl. If we admit that statement to be true, then we go on as follows—founding our conclusions upon facts that are equally true—in valeryl is butyl; in butyl is butyryl; in butyryl is propyl; in propyl is propionyl; in propionyl is ethyl; in ethyl is acetyl; in acetyl is methyl; in methyl is formyl; in formyl is hydrogen. All these radicals therefore are contained in the radical of valerianic acid, granting only the truth of the assumption, that a radical CONTAINS what you can make it PRODUCE.

It is certain, that from the acid radicals you can *produce* the basic radicals. It is equally certain, that from the basic radicals you can *produce* the acid radicals: but when you jump from these facts to the inference, that these acid radicals and basic radicals respectively CONTAIN the corresponding basic radicals and acid radicals, *ready-formed*; you go astray. What a thing *has been*, or what a thing *may become*, is not the same as what a thing *is*. To confuse these ideas, or to use them indiscriminately, is a breach of scientific exactness. Experiment is our guide in such matters. Experiment shows us the composition of acetyl. It shows us how to convert ethyl into acetyl, and acetyl into methyl. Experiment shows us that acetate of potash contains those proportions of carbon and hydrogen, which constitute neither ethyl nor methyl, but acetyl. Such are the facts. According to these facts, we must judge of the merit of Kolbe's theory, that *acetate of potash contains not acetyl, but methyl*, a theory which appears to me to be a denial of facts.

The doctrine which leads chemists astray in matters of this sort is due to Gerhardt, who thus expounds it (*Introduction to Unitary Chemistry*):—

"In the dualistic system of chemistry, bodies are represented such as they exist (at the time of examination). This method is incompatible with the unitary system, which bases its definitions upon the metamorphoses of bodies, *i. e.*, upon their previous state, or upon their future combinations. In this respect it evidently attains the special aim of chemistry, viz., the discovery of the laws which govern the transformations of matter."

According to this doctrine, the special duty of chemists is to take cognisance of things which once *did exist*, or which may chance *to exist hereafter*, but to neglect the things which *do exist* at the time of examination. The unitary system disdains present existences, and only values the historical and the prophetical. To represent bodies as they exist is left for chemists who follow the despised dualistic system. The special aim of unitary chemists is directed above and beyond the department of actual existences. It deals only with the past and the future. Lighted by this luminary, we perceive that acetyl is not acetyl but once was ethyl, and may hereafter become methyl; that valeryl is not valeryl, but in the past was amyl, and in the future may be butyl. The brightness of this theoretical light renders invisible the things that are illuminated only by the dim medium of common sense. But that is evidently desirable. Radicals "such as they exist" are beneath the notice, and incompatible with the objects which unitary chemists specially aim at, under the guidance of this new light.

By a parity of reasoning, we discover in common life, that bankrupts and heirs-at-law are men of property; because a man's fortune consists, not in what he possesses, but in what in past times he has squandered away, or in what in the future he may chance to inherit. "The proper definition of a thing," says Gerhardt, "is not what it *is*, but what it *has been*, or what it may *become*." A man, whose fortune is a matter of history or a matter of expectancy, is, therefore, a man of fortune.

Professor Kolbe's copulated oxalates are the heirs-at-law of the acid radicals. When the acid radicals come to destruction—when they die the death—their substance is the inheritance of the copulated oxalates. But when the Professor argues, that the heirs-at-law are the present possessors of the estate, he anticipates the fact, and pronounces a judgment which is erroneous. A *present* acid must be held to contain a *present* radical.

The Malic Group of Salts.

The formula commonly assigned to MALIC ACID is:

$$(2HO,C^8H^4O^8), \text{ in which } H = 1, C = 6, O = 8;$$

and as the 2HO are replaceable by two other bases, this compound is an example of what is called a BIBASIC ACID.

I propose to consider it, not as a bibasic salt, but as a double salt, constituted in agreement with the following formula:

$$H,C^2H^3O^3 + H,C^2HO^2; \text{ in which } H = 1, C = 12, O = 16.$$

This formula contains two assumed acid radicals = C^2H^3 and C^2H. The former is equivalent in its proportions of elementary atoms to acetyl, and the latter to aconyl, fumaryl, maleyl, and perhaps to several other acid radicals. I do not know whether the radical C^2H^3 of the malic acid is the same thing as the radical C^2H^3 of the acetic acid, nor whether the radical C^2H is the same as any other radical of the same ultimate composition. I wish to give in this place no opinion respecting the identification of these isomeric radicals, and for the purposes of the present discussion, I shall indicate these *assumed radicals* by temporary names; thus:

C^2H^3 will be called Myl.
C^2H^1 ,, ,, Dyl.

In agreement with these assumptions, crystallised malic acid = $H^r,C^2H^3O^3 + H^r,C^2HO^2$, will be called *Hydra mylite cum hydra dylete.* The two atoms of H^r are both, or either, replaceable by other basic radicals, and the products of that replacement, combined in pairs, produce the salts that are called *malates.* The mylites and dyletes can separately undergo the various modifications to which all single salts are subject, without suffering separation from one another. As long as they remain conjoined, they constitute the malates. When the conjunction is dissolved, the products of the decomposition receive other names. Yet, while the mylites and dyletes continue in combination, their basic radicals sometimes undergo modifications which cause the compound salts to receive other names than malates, as will be seen in the description of the following examples:—

SALTS BELONGING TO THE MALIC GROUP.

Group A. *Malic Acid*, cryst.

1. $H,C^2H^3O^3 + H,C^2HO^2$ . . Hydra mylite cum hydra dylete.

Group B. *Neutral Malates.*

2.	$Ag,C^2H^3O^3 + Ag,C^2HO^2$	Argenta mylite cum argenta dylete.
3.	$Ca,C^2H^3O^3 + Ca,C^2HO^2$	Calca mylite cum calca dylete.
4.	$Pb,C^2H^3O^3 + Pb,C^2HO^2$	Plumba mylite cum plumba dylete.
5.	$Zn,C^2H^3O^3 + Zn,C^2HO^2$	Zinca mylite cum zinca dylete.
6.	$ZH^4,C^2H^3O^3 + ZH^4,C^2HO^2$	Ammona mylite cum ammona dylete.

Group C. *Acid Malates.*

7.	$Ca,C^2H^3O^3 + H,C^2HO^2$	Calca mylite cum hydra dylete.
8.	$Zn,C^2H^3O^3 + H,C^2HO^2$	Zinca mylite cum hydra dylete.
9.	$ZH^4,C^2H^3O^3 + H,C^2HO^2$	Ammona mylite cum hydra dylete.

Group D. *Double and Basic Malates.*

10.	$ZH^4,C^2H^3O^3 + Zn,C^2HO^2$	Ammona mylite cum zinca dylete.
11.	$Pb,C^2H^3O^3 + Pb^3,C^2HO^3$	Plumba mylite cum plumbine dylite.

Group E. *Amyl-Malates.*

12.	$C^5H^{11},C^2H^3O^3 + H,C^2HO^2$	Amyla mylite cum hydra dylete.
13.	$C^5H^{11},C^2H^3O^3 + Ca,C^2HO^2$	Amyla mylite cum calca dylete.
14.	$C^5H^{11},C^2H^3O^3 + ZH^4,C^2HO^2$	Amyla mylite cum ammona dylete.

Group F. *Aspartic Acid.*

15.	$ZH^2,C^2H^3O^2 + H,C^2HO^2$	Amida mylete cum hydra dylete.

Group G. *Aspartates*, Class *a.*

16.	$ZH^2,C^2H^3O^2 + K,C^2HO^2$	Amida mylete cum potassa dylete.
17.	$ZH^2,C^2H^3O^2 + Ba,C^2HO^2$	Amida mylete cum baryta dylete.
18.	$ZH^2,C^2H^3O^2 + Ag,C^2HO^2$	Amida mylete cum argenta dylete.

19.	$ZH^2,C^2H^3O^2 + Pb,C^2HO^2$.	Amida mylete cum plumba dylete.
20.	$ZH^2,C^2H^3O^2 + ZH^4,C^2HO^2$.	Amida mylete cum ammona dylete.

Group H. *Aspartates*, Class *b*.

21.	$ZHBa,C^2H^3O^2 + Ba,C^2HO^2$.	Barytac mylete cum baryta dylete.
22.	$ZHPb,C^2H^3O^2 + Pb,C^2HO^2$.	Plumbac mylete cum plumba dylete.
23.	$ZHAg,C^2H^3O^2 + Ag,C^2HO^2$	Argentac mylete cum argenta dylete.

Group I. *Aspartates*, Class *c*.

24.	$\left\{\begin{array}{l}ZH^2Pb,C^2H^3O^2 + Pb,C^2HO^2\\ ZH\ Pb,C^2H^3O^2 + Pb,C^2HO^2\end{array}\right\}$	Plumbam mylite cum plumbac mylete bis plumba dylete.

Group K. *Aspartic Acid with other Acids.*

25.	$\left\{\begin{array}{r}ZH^2,C^2H^3O^2 + H,C^2HO^2\\ HSO^2 + \quad\quad HSO^2\end{array}\right\}$	Amida mylete cum hydra dylete bis hydra sulphete.
26.	$\left\{\begin{array}{r}ZH^2,C^2H^3O^2 + H,C^2HO^2\\ HCl\end{array}\right\}$	Amida mylete cum hydra dylete cum hydra chlora.

Group L. *Asparagine.*

27.	$ZH^2,C^2H^3O^2 + ZH^2,C^2HO$.	Amida mylete cum amida dylate.

Group M. *Asparagine with Bases.*

28.	$ZH^2,C^4H^3O^2 + ZHK,C^2HO$.	Amida mylete cum potassac dylate.
29.	$ZH^2,C^2H^3O^2 + ZHAg,C^2HO$	Amida mylete cum argentac dylate.
30.	$ZH^2,C^2H^3O^2 + ZHCuc,C^2HO$	Amida mylete cum cupricac dylate.

Group N. *Asparagine with Acids.*

31.	$\left\{\begin{array}{r}ZH^2,C^2H^3O^2 + ZH^2,C^2HO\\ AgNO^3 + \quad\quad AgNO^3\end{array}\right\}$	Amida mylete cum amida dylate bis argenta nitrite.
32.	$\left\{\begin{array}{r}ZH^2,C^4H^3O^2 + ZH^2,C^2HO\\ HCO^2 + \quad\quad HCO^2\end{array}\right\}$	Amida mylete cum amida dylate bis hydra carbete.
33.	$\left\{\begin{array}{r}ZH^2,C^2H^3O^2 + ZH^2,C^2HO\\ H,Cl\end{array}\right\}$	Amida mylete cum amida dylate cum hydra chlora.

Group O. *Malic Phenyl Amides.*

34.	$ZH,C^6H^5; C^2H^3O^2+H,C^2HO^2$	Phenylac mylete cum hydra dylete.
35.	$ZH,C^6H^5; C^2H^3O^2+ZH^4,C^2HO^2$	Phenylac mylete cum ammona dylete.
36.	$ZH,C^6H^5; C^2H^3O^2+Ag,C^2HO^2$	Phenylac mylete cum argenta dylete.
37.	$ZH,C^6H^5; C^2H^3O^2+ZH,C^6H^5; C^2HO$.	Phenylac mylete cum phenylac dylate.
38.	$Z,C^2H^3,C^6H^5; C^2HO^3$ . . .	Mylic-phenylac dylite.

Group P. *Maleic Acid.*

39.	H,C^2HO^2	Hydra maleylete.

Group Q. *Maleates.*

40.	K,C^2HO^2	Potassa maleylete.
41.	$K,C^2HO^2 + H,C^2HO^2$ . .	Potassa hydra bimaleylete.
42.	Ag,C^2HO^2	Argenta maleylete.
43.	$Ag,C^2HO^2 + H,C^2HO^2$ . .	Argenta hydra bimaleylete.
44.	ZH^4,C^2HO^2	Ammona maleylete.
45.	$ZH^4,C^2HO^2 + H,C^2HO^2$ . .	Ammona hydra bimaleylete.
46.	Pb,C^2HO^2	Plumba maleylete.
47.	Cuc,C^2HO^2	Cupric maleylete.
48.	$ZH^3Cuc,C^2HO^2 + Aq.$ . .	Cupricam maleylete aquate.

Group R. *Fumaric Acid.*

49.	H,C^2HO^2	Hydra fumarylete.

Group S. *Fumarates.*

50.	K,C^2HO^2	Potassa fumarylete.
51.	$K,C^2HO^2 + H,C^2HO^2$ . .	Potassa hydra bifumarylete.
52.	Ag,C^2HO^2	Argenta fumarylete.
53.	ZH^4,C^2HO^2	Ammona fumarylete.
54.	$ZH^4,C^2HO^2 + H,C^2HO^2$ . .	Ammona hydra bifumarylete.
55.	Pb,C^2HO^2	Plumba fumarylete.
56.	$Pb,C^2HO^2 + Pb,PbO$ . .	Plumbine fumarylite.
57.	$(Pb,C^2HO^2)^4 + Pb,PbO$.	Tetrakis plumba fumarylete cum plumba plumbate.
58.	$(Fec,C^2HO^2)^4 + Fec,FecO$.	Tetrakis ferric fumarylete cum ferric ferrate.
59.	C^2H^5,C^2HO^2	Ethyla fumarylete.

Group T. *Fumaric Amides.*

60.	C^2H,C^2HO^3	Fumaryla fumarylite.
61.	ZH^2,C^2HO	Amida fumarylate.
62.	$ZH,C^2H ; C^2HO^2$	Fumarylac fumarylete.
63.	$Z,C^2H^3,C^2H^3 ; Z,C^2H,C^2HO^5$	Mylec dylecute.
64.	$ZH^2,C^2HO+ZH^2Hgc^2 ; C^2HO^2$	Amida fumarylate cum mericcem fumarylete.

USUAL NAMES AND FORMULÆ OF THESE SALTS.

Group A. *Malic acid in crystals*:—1. $H,C^2H^3O^3 + H,C^2HO^2$. Hydra mylite cum hydra dylete.

This formula represents, as I have already stated, the crystallised malic acid. Usual formulæ: $C^8H^6O^{10} = C^8H^6O^4,O^6$, *Gmelin*. $2HO, C^8H^4O^8$, *Miller*. These formulæ represent the acid as bibasic, with an acid radical $= C^4H^4$. For an account of the Decompositions of Malic Acid, see the subsequent particulars respecting the reactions of salts of the Malic group, Nos. 1 and 2. Its production from aspartic acid; see Reactions, No. 6, page 422.

Group B. *Neutral Malates.* General formula: $C^8H^4M^2O^{10}$. 2, Malate of silver. 3, M. of lime. 4, M. of lead. 5, M. of zinc. 6, M. of ammonia.

Group C. *Acid Malates.* General formulæ: $C^8H^5M^1O^{10}$. 7, Bimalate of lime. 8, Bimalate of zinc. 9, Bimalate of ammonia. Decomposition of bimalate of ammonia by heat. See Reactions, No. 3.

Group D. *Double and Basic Malates.* 10, Double malate of zinc and ammonium. 11, Basic malate of lead. In this salt, the radical Dyl is in the condition of a terbasic salt, according to the usual terbasic formula $Pb,C^2HO^2 + Pb,PbO = Pb^3,C^2HO^3$. A considerable number of the malates contain water, and might have formulæ in accordance with No. 11. Thus, the bimalate of ammonia No. 9, in the crystallised state, might have the formula $ZH^4,C^2H^3O^3 + H^3,C^2HO^3$.

Group E. *Amyl-Malates.* 12, Amyl-malic acid $= C^{18}H^{16}O^{10} = C^8H^5(C^{10}H^{11})O^{10}$. 13, Amyl-malate of lime $= C^{18}H^{15}CaO^{10}$. 14, Amyl-malate of ammonia $= C^{18}H^{15}(NH^4)O^{10}$. *Gerhardt*, after *Breunlin.*

Here we have a "conjugated acid" and its salts; but according to my notation, No. 12 is a bimalate, precisely equivalent to No. 7, and Nos. 13 and 14 are double salts equivalent to No. 10. It is certain that similar salts could be prepared with other radicals instead of amyl, and there is no necessity to make conjugated acids of any of them.

Group F. No. 15. *Aspartic acid*, or *Malamic acid.* Compare this compound with the Bimalate of ammonia No. 9, thus:—

No. 9 $= ZH^4,C^2H^3O^3 + H,C^2HO^2$. Ammona mylite cum hydra dylete.
No. 15 $= ZH^2,C^2H^3O^2 + H,C^2HO^2$. Amida mylete cum hydra dylete.
$H^2 \quad O^1$ = *Difference.*

On referring to page 225, it will be seen, that the difference between binoxalate of ammonia and oxamic acid is precisely the same as the difference between bimalate of ammonia and aspartic acid. Aspartic acid, like oxamic acid, produces a series of salts, and it is, like oxamic acid, a double salt, with the single difference, that its two acid radicals are not alike. Production of aspartic acid from the hydrochlorate, see Reactions, No. 5, page 422. Its conversion into malic acid, see Reactions, No. 6. Its production from asparagine; Reactions, Nos. 7 and 8.

Chemists are not agreed as to the basicity of aspartic acid; but the investigators have pointed out three varieties of salts, answering to the formulæ $C^8NH^6MO^8$ (= class *a*), $C^8NH^5M^2O^8$ (= class *b*), and $MO, C^8NH^6MO^8$ (= class *c*), of each of which I have quoted some examples, Nos. 16 to 24. See Gmelin (*Handbook of Chemistry*, 1856, x. 234).

Group G. Nos. 16 to 20. The salts of this group are evidently monobasic aspartates, formed in exact accordance with the oxamates; see page 226, but differing in the quantity of oxygen, and in having two dissimilar, instead of two similar, acid radicals. Production of aspartate of ammonia, No. 20, from asparagine, No. 27. See Reactions, No. 9, page 422.

Group H. Nos. 21 to 23. These salts, of which many more might be cited, containing the radicals Ca, Cuc, &c., differ from those of group G, by containing metallic vice-amids instead of normal amid; but they are alike in all other respects. As chemists are not accustomed to admit the existence of these metallic vice-amids, this little group of salts has puzzled them greatly. Gmelin says, "As it is improbable that an amidogen acid should be bibasic, and as Liebig has not given the mode of preparation of the salt which he analysed, Laurent doubts its purity." To which Mr. Watts adds, "Liebig's result is, however, confirmed by those of Dessaignes, Pasteur, and Wolff." The analyses are no doubt correct, and they confirm the accuracy of the theory that I have advanced respecting the nature of these metallic vice-radicals.

Group I. No. 24. *Aspartates*, class *c*. Several similar salts occur, in which Pb is replaced by the radicals Ba, Ca, Ag, and Hgc. This salt is evidently intermediate between the malates and the aspartates; that is to say, it is a combination of a malate with an aspartate, atom to atom. The upper half of the formula No. 24 is equivalent to the bimalate of ammonia No. 9, supposing ammonia ZH^4 to be replaced by plumbam ZH^3Pb, and H to be replaced by Pb, and the lower half of the formula is the same as that of the aspartate No. 22.

Group K, Nos. 25 and 26 are examples of salts produced by the combination of aspartic acid with mineral acids. No. 25 contains one atom of aspartic acid and two atoms of hydrated sulphuric acid. No. 26 contains aspartic acid and hydrochloric acid, atom to atom. See Reactions, Nos. 4 and 5, page 422.

Group L. No. 27. *Asparagine*, or *Malamide*, Gerhardt's *Diazoture of malyle and of hydrogen.* Formulæ: $C^8N^2H^8O^6 = C^8Ad^2H^4O^4,O^2$, *Gmelin.*

Compare formula 27 with formula 6, which represents the neutral malate of ammonia, from which the double amid is derived. The difference is equal to two atoms of HHO. Thus:

No. 6. $ZH^4,C^2H^3O^3 + ZH^4,C^2HO^2$ Ammona mylite cum ammona dylete.

No. 27. $ZH^2,C^2H^3O^2 + ZH^2,C^2HO$ Amida mylete cum amida dylate.

$H^2 \quad O^1 + H^2 \quad O^1 =$ *Difference.*

Again, compare this difference with the difference found to exist between No. 15 and No. 9. From these comparisons it appears that No. 9, the bimalate of ammonia, by losing one equivalent of water, is converted into aspartic acid, and that No. 6, the neutral malate of ammonia, on losing two equivalents of water, is converted into asparagine. The same comparison shows that aspartic acid is a regular amidogen acid, and that asparagine is a double amid. Gerhardt wishes us to consider asparagine as an ammonia, and he represents it by the following formula:

$$N^2 \begin{cases} C^4H^4O^3 \\ H^2 \\ H^2 \end{cases}$$

I have already so fully expressed the reasons why I disapprove of the proposal to formulate oxidised compounds as "ammonias," that I need not take special notice of this formula.—Conversion of asparagine into aspartic acid; see reactions, Nos. 7 and 8, page 422. Conversion into aspartate of ammonia, No. 20; reactions, No. 9.

The relations which the two ammoniacal salts, No. 6 and No. 9, bear to the amidogen acid No. 15 and the double amid No. 27, are, according to the general facts which I have developed in the section on the azotic radicals, such as to show that malic acid acts under all circumstances, as it necessarily must act if it contains TWO *acid radicals*, instead of only one. This being the case, it is but fair to assume, that, where we have the properties and powers of two radicals, these two radicals are present in substance.

Group M. *Combinations of Asparagine with bases.* Nos. 28 to 30.

Besides these three salts, other salts of similar structure are formed by the basic radicals Ca, Cd, Pb, Hgc, Zn, &c.

On comparing the formulæ of these salts with the formula of asparagine, No. 27, we perceive that the amount of the difference between them is, that one of the amids in No. 27 is replaced in the salts by a metallic amidac. *Usual names:* 28, Asparagine with potash. 29, Asparagine with silver oxide. 30, Asparagine with cupric oxide, *Gmelin.* Potassic, argentic, and cupric asparagine, *Gerhardt.* The latter says that ammonic asparagine appears to be unattainable; for if asparagine is dissolved in aqueous ammonia, and submitted to spontaneous evaporation, the ammonia flies off, and the solution yields crystals of pure asparagine. He offers no explanation of this difficulty. I suggest that it is due to the fact that ammonium = ZH^4 can never replace hydrogen in a vice-ammon or vice-amid—that one ammonium or amidogen cannot involve another. Hence the salt No. 27 can produce such salts as Nos. 28 to 30, but the metals K, Ag, and Cuc, though replaceable by many other metals, cannot be replaced by the radical ZH^4. Neither can ZH^2 in No. 27 be replaced by ZH^4, unless at the same time O^1 becomes O^2; but in that case, the ammonic asparagine would become aspartate of ammonia No. 20; or, if both atoms of ZH^2 were replaced by ZH^4, with O^1 additional for each radical, then the salt No. 27 would be converted into neutral malate of ammonia No. 6. Consequently, the production of ammonic asparagine is impossible.

Group N. *Combinations of Asparagine with hydrated acids and with salts of mineral acids.* Nos. 31 to 33.—No. 31 is a combination of one atom of asparagine with two atoms of nitrate of silver. No. 32 contains one atom of asparagine with two atoms of oxalic acid; No. 33 is a combination of one atom of asparagine with one atom of hydrochloric acid.

Group O. *Malic phenyl amides*, or *Anilides of malic acid.* Nos. 34 to 38. These salts have been described by *Arppe* (*Ann. der Chem. u. Phar.*, 1855, xcvi. 106). I quote from Gerhardt (*Traité de Chimie Organique*, tome iv., 915).

34. $ZH,C^6H^5; C^2H^3O^2 + H,C^2HO^2$. This compound is called Phenyl-malamic acid, or malanilic acid, and the formula given to it is $C^{20}H^{11}NO^8 = C^8H^6(C^{12}H^5)NO^8$. Compare it with aspartic acid. No. 15. The only difference between them is the replacement of normal amid by phenylac; thus:

$$\begin{aligned}\text{No. } 15 &= ZH^2 \qquad ; C^2H^3O^2 + H,C^2HO^2.\\ \text{No. } 34 &= ZH,C^6H^5; C^2H^3O^2 + H,C^2HO^2.\end{aligned}$$

Like aspartic (or malamic) acid, this compound, Phenyl-malamic acid, produces salts by exchanging H for basic radicals, of which salts Nos. 35 and 36 are examples. This acid is perfectly similar to the anilidogen acids described at letter D, page 228, save only that it has two different acid radicals, instead of two acid radicals of the same kind.

35. Phenyl-malamate of ammonia.

36. Phenyl-malamate of silver; formula $C^{20}H^{10}AgNO^{8}$.

37. Phenyl-malamide or malanilide; formula $C^{32}H^{16}N^{2}O^{6} = C^{8}H^{6}(C^{12}H^{5})^{2}N^{2}O^{6}$.

38. Phenyl-malimide, or malanile; formula $C^{20}H^{9}NO^{6} = C^{8}H^{4}(C^{12}H^{5})NO^{6}$.

The reactions of these salts are precisely conformable to what would necessarily be predicted of the reactions of anilidogen salts.

When the salt No. 38 is boiled with aqueous ammonia, it produces the salt No. 35. Thus:

$$\left.\begin{array}{r}Z,C^{6}H^{5},C^{2}H^{3};\ C^{2}HO^{3}\\ H\ ;\ ZH^{4}O\end{array}\right\} = \left\{\begin{array}{l}ZH,C^{6}H^{5};\ C^{2}H^{3}O^{2} + ZH^{4},C^{2}HO^{2}.\\ \ \end{array}\right.$$

This product is converted by barytic water into the phenyl-malamate of barytes $= ZH,C^{6}H^{5};\ C^{2}H^{3}O^{2} + Ba,C^{2}HO^{2}$, which can be converted by the action of sulphuric acid into the acid No. 34.

This acid is evidently the anilidogen acid corresponding to an unknown acid malate of phenylam, thus:

$$ZH^{3},C^{6}H^{5};\ C^{2}H^{3}O^{3} + H,C^{2}HO^{2} = \left\{\begin{array}{lcl}ZH,C^{6}H^{5};\ C^{2}H^{3}O^{2} & + & H,C^{2}HO^{2}.\\ H^{2}\qquad\qquad\quad O & & \end{array}\right.$$

The double amid No. 37 is in the same way derived from the unknown neutral malate of phenylam, thus:

$$\left\{\begin{array}{l}ZH^{3},C^{6}H^{5};\ C^{2}H^{3}O^{3}\\ ZH^{3},C^{6}H^{5};\ C^{2}H\ O^{2}\end{array}\right\} = \left\{\begin{array}{lcl}ZH,C^{6}H^{5};\ C^{2}H^{3}O^{2} & + & ZH,C^{6}H^{5};\ C^{2}HO.\\ H^{2}\qquad\qquad\qquad O & + & H^{2}\qquad\qquad\qquad O.\end{array}\right.$$

Finally, No. 38 is the "anile" (see page 224, letter *b*) produced by the abstraction of HHO from the "anilidogen acid" No. 34, thus:

$$ZH,C^{6}H^{5};\ C^{2}H^{3}O^{2} + H,C^{2}HO^{2} = \left\{\begin{array}{llll}Z & C^{6}H^{5};\ C^{2}H^{3}; & & C^{2}HO^{3}.\\ H & & ;\ H & O.\end{array}\right.$$

We perceive all through this set of changes that the acid radical of the malic acid, acts precisely as it must act if it consists of two different radicals. There are also, under all circumstances, present in each compound, exactly the number of atoms of oxygen and of basic radicals, which form the complement of two acid radicals, one possessing the power to form normal salts with O^{3}, and the other with O^{2}.

Group P. No. 39. *Maleic Acid.* Production of maleic acid. See Reactions, No. 1, page 420.

Group Q. Nos. 40 to 48. *Maleates.* Gerhardt terms this a bibasic acid, and gives it the formula $C^{8}H^{4}O^{8} = C^{8}H^{2}O^{6},2HO$. But there is not the slightest evidence to prove its possession of bibasic powers, excepting the occurrence of acid salts, such as are represented by Nos. 41, 43, 45.

I have shown, in respect to the sulphates and oxalates, that such acid salts, or double salts, cannot be accepted as examples of true bibasic salts, and, besides, many organic acids, universally admitted to be monobasic, exhibit examples of such acid salts. I may instance the acetates, the margarates, the stearates, and the benzoates. Gmelin's formulæ for maleic acid and its salts are as follows: $C^4H^2O^4$ = maleic acid; C^4HMO^4 = monomaleate; $C^4HMO^4,C^4H^2O^4$ = bimaleate. His formula for the ammonam salt No. 48 is $NH^4O,C^4HCuO^4 + Aq$.

Group R. No. 49. *Fumaric acid.* Production of fumaric acid. See Reactions, No. 1, page 420.

Group S. Nos. 50 to 59. *Fumarates.* The fumaric acid produces a few acid salts such as Nos. 51, and 54; but most of its salts are neutral, on the model of No. 50. It also produces basic salts, such as are represented by Nos. 56, 57, 58. It has been called a bibasic acid, but without necessity, and to no useful end. 59, Fumarate of ethyl. Decompositions: see Reactions, Nos. 10 and 11, page 422.

Group T. Nos. 60 to 64. *Fumaric Amides.* 60, Fumaric anhydride; anhydrous fumaric acid; anhydrous maleic acid = $C^8H^2O^6$. This may be supposed to result from the abstraction of two atoms of HHO from one atom of malic acid, No. 1:

$$H,C^2H^3O^3 + H,C^2HO^2 = \left\{ \begin{array}{l} {}_{H}{}^{,C^2H\,O} \; + \; {}_{H}{}^{,C^2HO^2} \\ \phantom{{}_{H}}H^2O^2 + \end{array} \right.$$

It is prepared by heating maleic or fumaric acid. Buchner gives an account of a salt produced by heating the bimaleate of magnesia (*Gmelin's Handbook*, viii. 157) which requires the following formula: $2(Mg,C^2HO^2) + C^2H,C^2HO^3$. This salt is equivalent in structure to the bichromate of potash. See page 126.

$$\begin{array}{lll} K^2 \quad Cr^4 \quad O^7 & = & \text{Bichromate of potash.} \\ Mg^2(C^2H)^4O^7 & = & \text{Bimaleate of magnesia.} \end{array}$$

61, Fumaramide = $C^8N^2H^6O^4$. Production; see Reactions No. 11. Decomposition; Reactions, Nos. 12 and 13, page 423. 62, Fumarimide = $C^8NH^3O^4$. 63, Hydrated fumarimide = $C^8NH^3O^4 + Aq$. Production; see Reactions, Nos. 3 and 14. 64, Fumaramide with mercuric oxide = $C^8N^2H^6O^4,2HgO$. These names and formulæ are quoted from Gmelin's *Handbook of Chemistry*, vol. x.

REACTIONS OF SALTS OF THE MALIC GROUP.

1. When malic acid, No. 1, is heated in a retort, it suffers decomposition and produces water, and either maleic acid, No. 39, or fumaric acid, No. 49. It depends upon the regulation of the heat and its duration, whether the chief product is maleic acid or fumaric acid.

$$H,C^2H^3O^3 + H,C^2HO^2 = (H,C^2HO^2)^2 + HHO.$$

A long-continued heat of about 180° C. produces the two acids in abont equal quantities. A suddenly-raised heat of 200° C. produces chiefly maleic acid. A long-continued heat of 150° C. converts malic acid chiefly into fumaric acid. There is nothing in these results which determines whether the salt H,C^2HO^2, which I have assumed to exist ready-formed in the malates, is the maleic or the fumaric acid, nor to show which of these acids is the product of the decomposition of $H,C^2H^3O^3$ into $H,C^2HO^2 + HHO$. Of the two isomeric acids (the maleic and the fumaric), the maleic seems to be most volatile; but it requires a higher degree of heat to volatilize it than that which suffices (if long-continued) to convert the malic acid, and the maleic also, into fumaric acid.

2. When malic acid is gently heated with oil of vitriol, it produces carbonic oxide gas (Döbereiner) and acetic acid (Liebig):

$$H,C^2H^3O^3 + H,C^2HO^2 = H,C^2H^3O^2 + (CO)^2 + HHO.$$

It is possible that the salt $H,C^2H^3O^3$ assumed to be contained in malic acid, may contain the radical of the acetic acid; but this production of acetic acid from malic acid is not alone sufficient to prove that that supposition is a fact. The circumstance that the malic-acid radical $= C^4H^4$ can readily produce the radical $= C^2H^1$, is another fact that leads to the idea that the malates may contain C^2H^3 as well as C^2H^1; it being at the same time pretty certain that C^4H^4 is NOT $C^2H^2 + C^2H^2$, which would make it a multiple of the succinic radical. While assuming that the radical of the malic acid consists of the two radicals C^2H^3 and C^2H^1, I do not pretend to be able to identify either of these radicals with other isomeric radicals. I only wish to demonstrate the probability, at least, of there being, in fact, two radicals and not one radical, present in malic acid, and thereby to explain the cause of the bibasic power of that acid. The identification of the individual radicals is a matter for experimental research.

3. When the bimalate of ammonia No. 9 is heated to 160°—200°, it gives off water, and is converted into the salt No. 63:

$$\left.\begin{array}{l} ZH^4,C^2H^3O^3 + H,C^2HO^2 \\ ZH^4,C^2H^3O^3 + H,C^2HO^2 \end{array}\right\} = \left\{\begin{array}{l} Z,C^2H^3,C^2H^3;\ Z,C^2H,C^2HO^5 \\ 5(H,HO). \end{array}\right.$$

This is also produced when the hydrochlorate of aspartic acid No. 26 is exposed to heat:

$$\left.\begin{array}{l} ZH^2,C^2H^3O^2 + H,C^2HO^2 + HCl \\ ZH^2,C^2H^3O^2 + H,C^2HO^2 + HCl \end{array}\right\} = \left\{\begin{array}{l} Z,C^2H^3,C^2H^3;\ Z,C^2H,C^2HO^5 \\ 2(HCl) + 3(H,HO). \end{array}\right.$$

Chemists are not agreed respecting the composition of the salt No. 63. It is sometimes called Aspartic acid *minus* water $= C^8NH^7O^8 - 3HO$. Sometimes it is said to be hydrated fumarimide $= C^8NH^3O^4 + Aq$. It seems to be a salt in which two amidecs include all the acid radicals of the two decomposed salts. I have given examples of such salts in the indigo series, at page 265.

4. When the compound No. 63 is boiled with hydrochloric acid, it produces the crystalline hydrochlorate of aspartic acid, No. 26.

$$\left.\begin{array}{l}\mathrm{Z,C^2H^3,C^2H^3;\ Z,C^2H,C^2HO^5} \\ \mathrm{2(HCl) + 3(H,HO)}\end{array}\right\} = \left\{\begin{array}{l}\mathrm{ZH^2,C^2H^3O^2 + H,C^2HO^2 + HCl.} \\ \mathrm{ZH^2,C^2H^3O^2 + H,C^2HO^2 + HCl.}\end{array}\right.$$

5. When the hydrochlorate of aspartic acid, No. 26, is dissolved in hot water, the solution divided into two equal parts, the one saturated with ammonia and the other added to it, the mixture thus formed yields on cooling an abundant crystallization of aspartic acid. [The hydrochloric acid being separated in the state of sal-ammoniac.]

6. When aspartic acid, No. 15, is acted upon by nitrous acid in the presence of nitric acid, nitrogen is disengaged and malic acid produced:

$$\left.\begin{array}{r}\mathrm{ZH^2,C^2H^3O^2 + H,C^2HO^2} \\ \mathrm{H,NO^2}\end{array}\right\} = \left\{\begin{array}{r}\mathrm{H,C^2H^3O^3 + H,C^2HO^2} \\ \mathrm{N,N + HHO.}\end{array}\right.$$

Here, the reaction seems to be entirely restricted to the amidogen salt.

7. Diluted sulphuric acid converts asparagine, No. 27, into ammonia and aspartic acid, No. 15:

$$\left.\begin{array}{c}\mathrm{ZH^2,C^2H^3O^2 + ZH^2,C^2HO} \\ \mathrm{H,SO^2 + H,HO}\end{array}\right\} = \left\{\begin{array}{c}\mathrm{ZH^2,C^2H^3O^2 + H,C^2HO^2} \\ \mathrm{ZH^4,SO^2}\end{array}\right.$$

8. The solution of asparagine, in strong hydrochloric acid evaporated at a gentle heat, leaves sal-ammoniac and aspartic acid:

$$\left.\begin{array}{c}\mathrm{ZH^2,C^2H^3O^2 + ZH^2,C^2HO} \\ \mathrm{HCl + HHO}\end{array}\right\} = \left\{\begin{array}{c}\mathrm{ZH^2,C^2H^3O^2 + H,C^2HO^2} \\ \mathrm{ZH^4,Cl}\end{array}\right.$$

9. When asparagine, No. 27, dissolved in water, is sealed in a glass tube, and heated till the pressure amounts to three or four atmospheres, it is converted into aspartate of ammonia, No. 20, without liberation of any permanent gas:

$$\left.\begin{array}{r}\mathrm{ZH^2,C^2H^3O^2 + ZH^2,C^2HO} \\ \mathrm{H^2,\quad O}\end{array}\right\} = \left\{\begin{array}{l}\mathrm{ZH^2,C^2H^3O^2 + ZH^4,C^2HO^2} \\ \end{array}\right.$$

10. The fumaric ether or fumarate of ethyl, No. 59, is converted by hydrate of potash into fumarate of potash, No. 50, and alcohol:

$$\mathrm{C^2H^5,C^2HO^2 + KHO = H,C^2H^5O + K,C^2HO^2.}$$

11. The same ether is converted by aqueous ammonia into alcohol, water, and fumaramide, No. 61:

$$\left.\begin{array}{l}\mathrm{C^2H^5,C^2HO^2} \\ \mathrm{ZH^4,HO}\end{array}\right\} = \left\{\begin{array}{l}\mathrm{H,C^2H^5O + H,HO} \\ \mathrm{ZH^2,C^2HO}\end{array}\right.$$

12. When fumaramide, No. 61, is heated for some time with water, it is converted into fumarate of ammonia No. 53:

$$ZH^2,C^2HO + HHO = ZH^4,C^2HO^2.$$

13. When fumaramide is heated with aqueous potash, it gives off ammonia, and produces fumarate of potash, No. 50.

$$ZH^2,C^2HO + KHO = K,C^2HO^2 + ZH^2H.$$

14. The hydrated fumarimide, No. 63, see Reactions, No. 3, is decomposed by water, and yields fumarimide, No. 62:

$$Z,C^2H^3,C^2H^3 ; Z,C^2H,C^2HO^5 = \begin{cases} ZH,C^2H ; C^2HO^2 \\ ZH,C^2H ; C^2HO^2 \\ \quad\quad\;\; H ; H \;\; O. \end{cases}$$

If we disregard the slight differences in properties which distinguish the maleates from the fumarates, we have good grounds for considering that the formula which I have assigned to malic acid is the true one, and that it is not a bibasic acid, but a compound of two monobasic acids:

$$H,C^2H^3O^3 + H,C^2HO^2.$$

All the chemical reactions among the malates and the products of their decomposition are such as ought to occur if this supposition were true; and in opposition to it, we have only the bare, vague, unproved notion, that the radical of a bibasic acid possesses all the powers and properties of the radicals of two monobasic acids. I have no faith in that doctrine. It seems to me to be demonstrated by the universal properties of radicals, that every one of them, as long as it continues to be an independent radical, has, under all circumstances, the saturating capacity of one volume or one atom, a chemical force which nothing can alter. The idea, that one acid radical can neutralise two basic radicals, or, as it is phrased, become bibasic, is in opposition to the essence of a radical. Only when the materials which constitute a radical pass into the form of a different radical, can its saturating capacity change. One radical may be split into two radicals, or several radicals may combine to form one radical, as in the ammoniums. But every radical, so long as it preserves its identity, acts as a unit, as a single volume, a single atom. In strict terms, it cannot be bibasic nor biacid, and the existence of bibasic salts in any other sense than that which has been explained at page 397 is an impossibility.

The Citric Group of Salts.

The citric acid is commonly received as the Model "tribasic" acid of the organic series. Its formula is $3HO,C^{12}H^5O^{11}$, in which $3HO$ represent bases replaceable by $3MO$, by $2HO + MO$ or by $HO + 2MO$. If I double the atomic weights of the carbon and oxygen, and put this formula into the shape commonly adopted in this work, I produce $H^3,C^6H^5O^7$, where $C^6H^5O^7$ is a constant quantity, and H^3 are replaceable by any three basic radicals.

The tribasic theory of citric acid is due to Liebig. Several chemists have expressed an opinion that it is a compound acid. Berzelius seems to have considered it to contain two atoms of citric acid of the formula $(2C^4H^2O^4)$ and one atom of aconitic acid (C^4HO^3). Dumas assumed that it consisted of oxalic acid C^2O^3, acetic acid $C^4H^3O^3$, and oxal-acetic acid $C^4(H^2,C^2O^2)O^3$. Pebal thought that it contained one atom of C^4HO^3 and two atoms of $C^4H^2O^4$.

I adopt the idea that tribasic citric acid is a triple salt, containing not only three basic radicals, but also three acid radicals, and I propose to write the formula thus:

$$\left\{\begin{array}{l} H,C^2H^3O^3 \\ H,C^2H\,O^2 \\ H,C^2H\,O^2 \end{array}\right\}, \text{ or } H,C^2H^3O^3 + 2(H,C^2HO^2).$$

I shall apply to the radicals exhibited in this formulæ the same provisional names that I have used in the section on malic acid; and I propose to show by examples that all the citrates, and the salts that are derived from them, have the constitution and the chemical characters, which they would necessarily have, if the citrates were triple salts, formed in accordance with the above formula, and having not only three basic radicals, but three acid radicals, each possessing the power of independent chemical action.

EXAMPLES OF CITRATES.

$$1.\left\{\begin{array}{l} H\,,C^2H^3O^3 \\ H\,,C^2H\,O^2 \\ H\,,C^2H\,O^2 \end{array}\right\} \text{Hydra mylite bis hydra dylete.}$$

$$2.\left\{\begin{array}{l} K\,,C^2H^3O^3 \\ K\,,C^2H\,O^2 \\ K\,,C^2H\,O^2 \end{array}\right\} \text{Potassa mylite bis potassa dylete.}$$

$$3.\left\{\begin{array}{l} H\,,C^2H^3O^3 \\ K\,,C^2H\,O^2 \\ K\,,C^2H\,O^2 \end{array}\right\} \text{Hydra mylite bis potassa dylete.}$$

4. $\left\{\begin{array}{l}\mathrm{K,C^2H^3O^3}\\ \mathrm{H,C^2H\,O^2}\\ \mathrm{H,C^2H\,O^2}\end{array}\right\}$ Potassa mylite bis hydra dylete.

5. $\left\{\begin{array}{l}\mathrm{ZH^4,C^2H^3O^3}\\ \mathrm{K,C^2H\,O^2}\\ \mathrm{K,C^2H\,O^2}\end{array}\right\}$ Ammona mylite bis potassa dylete.

6. $\left\{\begin{array}{l}\mathrm{ZH^4,C^2H^3O^3}\\ \mathrm{H,C^2H^3O^2}\\ \mathrm{H,C^2H^3O^2}\end{array}\right\}$ Ammona mylite bis hydra dylete.

7. $\left\{\begin{array}{l}\mathrm{H,C^2H^3O^3}\\ \mathrm{ZH^4,C^2H\,O^2}\\ \mathrm{ZH^4,C^2H\,O^2}\end{array}\right\}$ Hydra mylite bis ammona dylete.

8. $\left\{\begin{array}{lcl}\mathrm{ZH^4,C^2H^3O^3} & & \mathrm{H,C^2H^3O^3}\\ \mathrm{ZH^4,C^2H\,O^2} & + & \mathrm{H,C^2H\,O^2}\\ \mathrm{ZH^4,C^2H\,O^2} & & \mathrm{H,C^2H\,O^2}\end{array}\right\}$ Ammona mylite bis ammona dylete cum hydra mylite bis hydra dylete.

9. $\left\{\begin{array}{lcl}\mathrm{K,C^2H^3O^3} & & \mathrm{Sbc,C^2H^3O^3}\\ \mathrm{K,C^2H\,O^2} & + & \mathrm{Sbc,C^2H\,O^2}\\ \mathrm{K,C^2H\,O^2} & & \mathrm{Sbc,C^2H\,O^2}\end{array}\right\}$ Potassa mylite bis potassa dylete cum stibic mylite bis stibic dylete.

10. $\left\{\begin{array}{lcl}\mathrm{Ba,C^2H^3O^3} & & \mathrm{H,C^2H^3O^3}\\ \mathrm{Ba,C^2H\,O^2} & + & \mathrm{Ba,C^2H\,O^2}\\ \mathrm{Ba,C^2H\,O^2} & & \mathrm{Ba,C^2H\,O^2}\end{array}\right\}$ Baryta mylite bis baryta dylete cum hydra mylite bis baryta dylete.

11. $\left\{\begin{array}{lcl}\mathrm{K,C^2H^3O^3} & & \mathrm{H,C^2H^3O^3}\\ \mathrm{K,C^2H\,O^2} & + & \mathrm{ZH^4,C^2H\,O^2}\\ \mathrm{K,C^2H\,O^2} & & \mathrm{ZH^4,C^2H\,O^2}\end{array}\right\}$ Potassa mylite bis potassa dylete cum hydra mylite bis ammona dylete.

12. $\left\{\begin{array}{lcl}\mathrm{Ag,C^2H^3O^3} & & \\ \mathrm{Sbc,C^2H\,O^2} & + & \mathrm{AgSbcO}\\ \mathrm{Sbc,C^2H\,O^2} & & \end{array}\right\}$ Argenta mylite bis stibic dylete cum argenta stibicate.

13. $\left\{\begin{array}{lclcl}\mathrm{Ag,C^2H^3O^3} & & \mathrm{Ca,C^2H^3O^3} & & \\ \mathrm{Ag,C^2H\,O^2} & + & \mathrm{Ca,C^2H\,O^2} & + & \mathrm{AgCaO}\\ \mathrm{Ag,C^2H\,O^2} & & \mathrm{Ca,C^2H\,O^2} & & \end{array}\right\}$ Argenta mylite bis argenta dylete cum calca mylite bis calca dylete cum argenta calcate.

14. $\left\{\begin{array}{l}\mathrm{C\,H^3,C^2H^3O^3}\\ \mathrm{C\,H^3,C^2H\,O^2}\\ \mathrm{C\,H^3,C^2H\,O^2}\end{array}\right\}$ Methyla mylite bis methyla dylete.

15. $\left\{\begin{array}{l}\mathrm{H,C^2H^3O^3}\\ \mathrm{C\,H^3,C^2H\,O^2}\\ \mathrm{C\,H^3,C^2H\,O^2}\end{array}\right\}$ Hydra mylite bis methyla dylete.

16. $\left\{\begin{array}{l}\mathrm{C\,H^3,C^2H^3O^3}\\ \mathrm{H,C^2H\,O^2}\\ \mathrm{H,C^2H\,O^2}\end{array}\right\}$ Methyla mylite bis hydra dylete.

$$17.\ \left\{\begin{array}{r}\mathrm{C^2H^5, C^2H^3O^2}\\ \mathrm{C^2H^5, C^2H\ O^2}\\ \mathrm{C^2H^5, C^2H\ O^2}\end{array}\right\}\text{Ethyla mylite bis ethyla dylete.}$$

$$18.\ \left\{\begin{array}{r}\mathrm{C^5H^{11}, C^2H^3O^3}\\ \mathrm{H\ , C^2H\ O^2}\\ \mathrm{H\ , C^2H\ O^2}\end{array}\right\}\text{Amyla mylite bis hydra dylete.}$$

$$19.\ \left\{\begin{array}{r}\mathrm{C^5H^{11}, C^2H^3O^3}\\ \mathrm{C^2H^5, C^2H\ O^2}\\ \mathrm{H\ , C^2H\ O^2}\end{array}\right\}\begin{array}{l}\text{Amyla mylite cum ethyla dylete}\\ \text{cum hydra dylete.}\end{array}$$

$$20.\ \left\{\begin{array}{r}\mathrm{C^5H^{11}, C^2H^3O^2}\\ \mathrm{ZH^4, C^2H\ O^2}\\ \mathrm{ZH^4, C^2H\ O^2}\end{array}\right\}\text{Amyla mylite bis ammona dylete.}$$

$$21.\ \left\{\begin{array}{r}\mathrm{C^5H^{11}, C^2H^3O^3}\\ \mathrm{K\ , C^2H\ O^2}\\ \mathrm{H\ , C^2H\ O^2}\end{array}\right\}\begin{array}{l}\text{Amyla mylite cum potassa dylete}\\ \text{cum hydra dylete.}\end{array}$$

$$22.\ \left\{\begin{array}{r}\mathrm{ZH^2, C^2H^3O^2}\\ \mathrm{ZH^2, C^2H\ O}\\ \mathrm{ZH^2, C^2H\ O}\end{array}\right\}\text{Amida mylete bis amida dylate.}$$

$$23.\ \left\{\begin{array}{r}\mathrm{ZH^3, C^6H^5;\ C^2H^3O^2}\\ \mathrm{H\ ,\ C^2H\ O^2}\\ \mathrm{H\ ,\ C^2H\ O^2}\end{array}\right\}\begin{array}{l}\text{Phenylam mylite bis hydra}\\ \text{dylete.}\end{array}$$

$$24.\ \left\{\begin{array}{r}\mathrm{ZH\ , C^6H^5;\ C^2H^3O^2}\\ \mathrm{Ag;\ C^2H\ O^2}\\ \mathrm{Ag;\ C^2H\ O^2}\end{array}\right\}\begin{array}{l}\text{Phenylac mylite bis argenta}\\ \text{dylete.}\end{array}$$

$$25.\ \left\{\begin{array}{r}\mathrm{H;\ C^2H^3O^3}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\end{array}\right\}\begin{array}{l}\text{Hydra mylite bis phenylac}\\ \text{dylate.}\end{array}$$

$$26.\ \left\{\begin{array}{r}\mathrm{Ag;\ C^2H^3O^3}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\end{array}\right\}\begin{array}{l}\text{Argenta mylite bis phenylac}\\ \text{dylate.}\end{array}$$

$$27.\ \left\{\begin{array}{r}\mathrm{Ba;\ C^2H^3O^3}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\end{array}\right\}\begin{array}{l}\text{Baryta mylite bis phenylac}\\ \text{dylate.}\end{array}$$

$$28.\ \left\{\begin{array}{r}\mathrm{ZH^3, C^6H^5;\ C^2H^3O^3}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\end{array}\right\}\begin{array}{l}\text{Phenylam mylite bis phe-}\\ \text{nylac dylate.}\end{array}$$

$$29.\ \left\{\begin{array}{r}\mathrm{ZH\ , C^6H^5;\ C^2H^3O^2}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\\ \mathrm{ZH\ , C^6H^5;\ C^2H\ O}\end{array}\right\}\begin{array}{l}\text{Phenylac mylete bis pheny-}\\ \text{lac dylate.}\end{array}$$

$$30.\ \left\{\begin{array}{r}\mathrm{ZH\ \ , C^6H^5;\ C^2H^3O^2}\\ \mathrm{Z, C^2H, C^6H^5;\ C^2H\ O^2}\end{array}\right\}\begin{array}{l}\text{Phenylac mylete cum dy-}\\ \text{lic-phenylac dylete.}\end{array}$$

31. $\left\{\begin{array}{r} H ; C^2H^3O^3 \\ Z,C^2H,C^6H^5 ; C^2H\,O^2 \end{array}\right\}$ Hydra mylite cum dylic-phenylac dylete.

32. $\left\{\begin{array}{r} Ag ; C^2H^3O^3 \\ Z,C^2H,C^6H^5 ; C^2H\,O^2 \end{array}\right\}$ Argenta mylite cum dylic-phenylac dylete.

EXAMPLES OF ACONITES.

33. $H\ ,C^2HO^2$ Hydra aconylete.

34. $Ag\ ,C^2HO^2$ Argenta aconylete.

35. C^2H^5,C^2HO^2 Ethyla aconylete.

36. $\left\{\begin{array}{l} K\ ,C^2HO^2 \\ H\ ,C^2HO^2 \end{array}\right\}$ Potassa aconylete cum hydra aconylete.

37. $\left\{\begin{array}{l} K\ ,C^2HO^2 \\ 2(H,C^2HO^2) \end{array}\right\}$ Potassa aconylete bis hydra aconylete.

38. $\left\{\begin{array}{l} ZH^4,C^2HO^2 \\ H\ ,C^2HO^2 \end{array}\right\}$ Ammona aconylete cum hydra aconylete.

39. $\left\{\begin{array}{l} ZH^4,C^2HO^2 \\ 2(H,C^2HO^2) \end{array}\right\}$ Ammona aconylete bis hydra aconylete.

40. $\left\{\begin{array}{r} Z,C^2H,C^6H^5 ; C^2HO^2 \\ H ; C^2HO^2 \end{array}\right\}$ Aconylic-phenylac aconylete cum hydra aconylete.

41. $\left\{\begin{array}{r} Z,C^2H,C^6H^5 ; C^2HO^2 \\ Ag ; C^2HO^2 \end{array}\right\}$ Aconylic-phenylac aconylete cum argenta aconylete.

42. $\left\{\begin{array}{l} Z,C^2H,C^6H^5 ; C^2HO^2 \\ ZH,\quad C^6H^5 ; C^2HO \end{array}\right\}$ Aconylic-phenylac aconylete cum phenylac aconylate.

EXAMPLES OF CITRACONATES.

43. $\left\{\begin{array}{l} H\ ,C^3H^3O^2 \\ H\ ,C^2H\,O^2 \end{array}\right\}$ Hydra trylete cum hydra dylete.

44. C^3H^3,C^2HO^3 Tryla dylite.

45. $\left\{\begin{array}{l} H\ ,C^3H^3O^2 \\ ZH^4,C^2H\,O^2 \end{array}\right\}$ Hydra trylete cum ammona dylete.

46. $\left\{\begin{array}{l} H\ ,C^3H^3O^2 \\ Ag,C^2H\,O^2 \end{array}\right\}$ Hydra trylete cum argenta dylete.

47. $\left\{\begin{array}{l} Ag,C^3H^3O^2 \\ Ag,C^2H\,O^2 \end{array}\right\}$ Argenta trylete cum argenta dylete.

48. $\left\{\begin{array}{l} C^2H^5,C^3H^3O^2 \\ C^2H^5,C^2H\,O^2 \end{array}\right\}$ Ethyla trylete cum ethyla dylete.

49. $\left\{\begin{array}{l} Pb\ ,C^3H^3O^2 \\ Pb^3,C^2H\,O^3 \end{array}\right\}$ Plumba trylete cum plumbine dylite.

50. $\left\{\begin{array}{l} C^3H^3,ClO \\ C^2H\ ,ClO \end{array}\right\}$ Tryla chlorate cum dyla chlorate.

51. $\mathrm{ZH,C^3H^3;\ C^2HO^2}$ Trylac dylete.

52. $\left\{\begin{matrix}\mathrm{ZH^2,C^2H\,O} \\ \mathrm{H\ ,C^3H^3O^2}\end{matrix}\right\}$ Amida dylate cum hydra trylete.

53. $\left\{\begin{matrix}\mathrm{ZH^2,C^2H\,O} \\ \mathrm{Ba\ ,C^3H^3O^2}\end{matrix}\right\}$ Amida dylate cum baryta trylete.

54. $\left\{\begin{matrix}\mathrm{ZH,C^6H^5;\ C^3H^3O} \\ \mathrm{ZH,C^6H^5;\ C^2H\,O}\end{matrix}\right\}$ Phenylac trylate cum phenylac dylate.

55. $\left\{\begin{matrix}\mathrm{ZH,C^6H^5;\ C^3H^3O} \\ \mathrm{H\ ;\ C^2H\,O^2}\end{matrix}\right\}$ Phenylac trylate cum hydra dylete.

56. $\left\{\begin{matrix}\mathrm{ZH,C^6H^5;\ C^3H^3O} \\ \mathrm{ZH^4;\ C^2H\,O^2}\end{matrix}\right\}$ Phenylac trylate cum ammona dylete.

57. $\left\{\begin{matrix}\mathrm{ZH,C^6H^5;\ C^3H^3O} \\ \mathrm{Ba;\ C^2H\,O^2}\end{matrix}\right\}$ Phenylac trylate cum baryta dylete.

58. $\mathrm{Z,C^3H^3,C^6H^5\ ;\ C^2H\,O^2}$ Trylic-phenylac dylete.

59. $\mathrm{Z,C^3H^3,C^6H^4I;\ C^2H\,O^2}$ Trylic - iodic - phenylac dylete.

60. $\mathrm{Z,C^3H^3,C^6H^3Z^2;\ C^2HO^6}$ Trylic-zotenic-phenylac dylaze.

61. $\left\{\begin{matrix}\mathrm{ZH,C^6H^3Z^2;\ C^3H^3O^5} \\ \mathrm{H;\ C^2H\,O^2}\end{matrix}\right\}$ Zotenic-phenylac trylute cum hydra dylete.

62. $\left\{\begin{matrix}\mathrm{ZH,C^6H^3Z^2;\ C^3H^3O^5} \\ \mathrm{Ag;\ C^2H\,O^2}\end{matrix}\right\}$ Zotenic-phenylac trylute cum argenta dylete.

INVESTIGATION OF THE CITRATES.

1]. $\mathrm{H,C^2H^3O^3 + 2(H,C^2HO^2)}$. Hydra mylite bis hydra dylete.

The hydrated citric acid. In this acid there are three atoms of hydrogen which are all, or one, or two of them, replaceable by other basic radicals, giving rise to the three kinds of salts which characterise the citrates, and which are illustrated by examples in Nos. 2, 3, and 4.

There are three varieties of citric acid obtainable in the solid state, in accordance with the following formulæ:

$$\text{A).}\ \mathrm{H,C^2H^3O^3 + 2(H,C^2HO^2)}.$$
$$\text{B).}\ \mathrm{H,C^2H^3O^3 + 2(H,C^2HO^2)\quad + HHO}.$$
$$\text{C).}\ \left\{\begin{matrix}\mathrm{H,C^2H^3O^3 + 2(H,C^2HO^2)} \\ \mathrm{H,C^2H^3O^3 + 2(H,C^2HO^2)}\end{matrix}\right\} + \mathrm{HHO}.$$

A). The acid which corresponds with the normal salts. It is produced by heating the crystallised acids to 212° F. B). The commercial acid, which crystallises when the solution is slowly evaporated. Its ordinary formula is $\mathrm{(3HO,C^{12}H^5O^{11},2\,aq.)}$. C). This acid is produced by saturating the solution at 212°, and allowing it to cool and crystallise. Compare the acids B and C with the salts Nos. 12 and 13, which have corresponding formulæ.

2]. $K,C^2H^3O^3 + 2(K,C^2HO^2)$ = Trimetallic citrate.
3]. $H,C^2H^3O^3 + 2(K,C^2HO^2)$ = Bimetallic.
4]. $K,C^2H^3O^3 + 2(H,C^2HO^2)$ = Monometallic.

5]. $ZH^4,C^2H^3O^3 + 2(K,C^2HO^2)$.

This is an example of a neutral, or trimetallic salt, which has different metals as basic radicals.

6]. $ZH^4,C^2H^3O^3 + 2(H,C^2HO^2)$.

Monometallic or acid salt of ammonium; of the same order as the potassium salt No. 4.]

7]. $H,C^2H^3O^3 + 2(ZH^4,C^2HO^2)$.

Bimetallic salt of ammonium, corresponding to the potassium salt No. 3].

The trimetallic salt of ammonium = $ZH^4,C^2H^3O^3 + 2(ZH^4,C^2HO^2)$, can only be prepared in solution; but No. 22 represents the amidogen salt which corresponds to it.

A great number of citrates are formed according to one or other of these three models. It is useless to quote them, because the fact will not be contested. It is sufficient to say, that these are the common forms of the citrates, and that they may all be represented as triple salts.

8]. $$\left\{\begin{array}{l} ZH^4,C^2H^3O^3 + 2(ZH^4,C^2HO^2) \\ H,C^2H^3O^3 + 2(H,C^2HO^2) \end{array}\right\}$$

9]. $$\left\{\begin{array}{l} K,C^2H^3O^3 + 2(K,C^2HO^2) \\ Sbc,C^2H^3O^3 + 2(Sbc,C^2HO^2) \end{array}\right\}$$

10]. $$\left\{\begin{array}{l} Ba,C^2H^3O^3 + 2(Ba,C^2HO^2) \\ H,C^2H^3O^3 + 2(Ba,C^2HO^2) \end{array}\right\}$$

11]. $$\left\{\begin{array}{l} K,C^2H^3O^3 + 2(K,C^2HO^2) \\ H,C^2H^3O^3 + 2(ZH^4,C^2HO^2) \end{array}\right\}$$

Nos. 8, 9, 10, 11 are examples of double citrates, each of which contains six monobasic salts, all in the proportions necessary to constitute citrates. The relation of these salts to the simpler kinds, Nos. 1 to 7, is so evident on an inspection of the formulæ, that comment appears to be needless.

12]. $Ag,C^2H^3O^3 + 2(Sbc,C^2HO^2) + AgSbcO$.

13]. $$\left\{\begin{array}{l} Ag,C^2H^3O^3 + 2(Ag,C^2HO^2) \\ Ca,C^2H^3O^3 + 2(Ca,C^2HO^2) \end{array}\right\} + AgCaO.$$

In No. 12, one atom of a citrate is combined with a salt on the model of water. In No. 13, two atoms of a citrate are combined with a salt on the model of water. These two models are not uncommon among the citrates. If all the radicals of both formulæ except C^2H^3 and C^2H were exchanged for hydrogen, the salts would resemble the crystallised acids B and C, No. 1. The structure of these salts becomes intelligible, if we assume that the mylite which forms part of them is subject to become terbasic. No. 12 would then be represented thus:—

$Sbc^3,C^2H^3O^4 + 2(Ag,C^2HO^2)$ = Stibinic mylote bis argenta dylete.

The corresponding crystallised acid (B, No. 1) would be:

$H^3,C^2H^3O^4 + 2(H,C^2HO^2)$ = Hydrine mylote bis hydra dylete.

In these cases, I separate the citrate into three salts which are monobasic in general, but one of which is, in these examples, terbasic.

14]. $CH^3,C^2H^3O^3 + 2(CH^3,C^2HO^2)$.
15]. $H\ ,C^2H^3O^3 + 2(CH^3,C^2HO^2)$.
16]. $CH^3,C^2H^3O^3 + 2(\ H\ ,C^2HO^2)$.

These three salts are the citrates of methyl. A comparison of Nos. 14, 15, and 16, with Nos. 2, 3, and 4, shows that the salts are precisely the same, excepting that the potassium of the latter is replaced in the former by methyl, atom for atom. Yet Gerhardt and other chemists give to the salts Nos. 15 and 16 the denomination of "conjugated acids." No. 15 is their Methyl-citric acid, and No. 16 is their Dimethyl-citric acid. The only ground for this assumption is, that salts of lime can be formed with these "acids." In that case, we have

with No. 15, $Ca\ ,C^2H^3O^3 + 2(CH^3,C^2HO^2)$.
with No. 16, $CH^3,C^2H^3O^3 + 2(Ca,\ C^2HO^2)$.

Both of these salts are citrates equally with Nos. 15 and 16, and ought not to be removed from that class merely to make imaginary conjugated acids. There is not a particle of evidence to prove that the methyl and the citric radicals are conjugated into a single acid radical. Methyl-citric acid and Dimethyl-citric acid are phantoms.

17]. $C^2H^5\ ,C^2H^3O^3 + C^2H^5,C^2HO^2 + C^2H^5,C^2HO^2$.
18]. $C^5H^{11},C^2H^3O^3 + \ H\ ,C^2HO^2 + \ H\ ,C^2HO^2$.
19]. $C^5H^{11},C^2H^3O^3 + C^2H^5,C^2HO^2 + \ H\ ,C^2HO^2$.
20]. $C^5H^{11},C^2H^3O^3 + ZH^4,C^2HO^2 + ZH^4,C^2HO^2$.
21]. $C^5H^{11},C^2H^3O^3 + \ K\ ,C^2HO^2 + \ H\ ,C^2HO^2$.

According to my method of looking at these salts they are all citrates, triple salts formed in exact accordance with the constitution of citric acid, and with the varieties of metallic citrates described above. But Gerhardt, reporting Breunlin's researches, will have the last four to be salts of "*conjugated acids.*" No. 18 is the Amyl-citric acid, Nos. 20 and 21 its salts, and No. 19 is the Ethylamyl-citric acid. In the amyl-citric acid, four radicals out of the six that are present in the salt are assumed to be conjugated into an acid radical, which then of course is bibasic. In the last example, five of the radicals (C^2H^3, C^2H, C^2H, C^5H^{11}, and C^2H^5,) are conjugated into one acid radical, which has H^1 to combine with as the corresponding and only remaining basic radical. The formulæ supplied for the last salt are $C^{26}H^{22}O^{14} = C^{12}H^6(C^4H^5)(C^{10}H^{11})O^{14}$. There is not the slightest necessity for this conglomerating process, nor has it any beneficial result. Conjugated acids are not merely enemies to the accurate discrimination of facts, and to the precise knowledge of intricate details: they are great high priests of false philosophy. In salt No. 19, if we consider it as a triple salt, we have an intelligible view of its composition; but if we regard it as "ethyl amyl-citric acid," we must suppose that two basic radicals, ethyl and amyl $= C^2H^5 + C^5H^{11}$, combine with the three acid radicals $= C^2H^3 + C^2H + C^2H$, to form a single acid radical $= C^{13}H^{21}$, which has then only a saturating capacity equal to H^1. What has become of the saturating capacities of all the component radicals which are assumed to be condensed into this mammoth radical? What proof have we that the radical $C^{13}H^{21}$ is really formed? None whatever.

22]. $ZH^2,C^2H^3O^2 + 2(ZH^2,C^2HO)$. CITRAMIDE.

This is the amid which corresponds to the unknown trimetallic or tribasic citrate of ammonia. That salt can be prepared in solution though it cannot be procured in crystals. I wish to draw attention to the fact, that as every one of the three atoms of ammonium belonging to this salt is converted into amid, every one of the three salts loses simultaneously one atom of oxygen, and the result is the production of an amidogen salt which contains only four atoms of oxygen instead of the seven atoms which belong to the normal citrate. Thus:

$$\begin{aligned} ZH^4,C^2H^3O^3 &= HHO + ZH^2,C^2H^3O^2. \\ ZH^4,C^2H\,O^2 &= HHO + ZH^2,C^2H\,O. \\ ZH^4,C^2H\,O^2 &= HHO + ZH^2,C^2H\,O. \end{aligned}$$

Now, if we knew to a certainty that the citrate of ammonia was a triple salt, consisting of one atom of $ZH^4,C^2H^3O^3$ and two atoms of ZH^4,C^2HO^2, this result is precisely what we must predicate as certain to occur on the occasion of its conversion into a triple amid. Conversely, therefore, the facts afford excellent evidence in proof of the triple nature of the acid radical of the citrates. Of this conclusion, the following details respecting the phenyl amids afford ample corroborative evidence:

$$\begin{array}{ll} 23]. & ZH^3,C^6H^5;\ C^2H^3O^3 + 2(\ H\ ,C^2HO^2). \\ 24]. & ZH\ ,C^6H^5;\ C^2H^3O^2 + 2(Ag,C^2HO^2). \end{array}$$

No. 23 is commonly called the Citrate of aniline. The other citrates, containing respectively two and three atoms of phenylam (ZH^3,C^6H^5) have not been discovered, though we are acquainted with their amids.

No. 24 is a salt in which the mylite of phenylam has been converted into an amid, the mylete of phenylac, while the two atoms of hydrated dylic acid have both been converted into dylate of silver. These changes prove unquestionably, that while the three salts which constitute a citrate remain in combination with one another, they yet individually retain their chemical powers unimpaired, and can exhibit the phases of all reactions to which they are respectively competent, as decidedly as if the tripartite union were dissolved.

No. 24 is described by Pebal as the silver salt of bibasic citromonanilic acid $= 2AgO,C^{24}H^{11}NO^{10}$. Here we have another "conjugated acid," which, like all the acids conjugated in this manner, is an unwarranted invention and a useless incumbrance.

$$\begin{array}{lll} 25]. & H, & C^2H^3O^3 + 2(ZH,C^6H^5;\ C^2HO). \\ 26]. & Ag, & C^2H^3O^3 + 2(ZH,C^6H^5;\ C^2HO). \\ 27]. & Ba, & C^2H^3O^3 + 2(ZH,C^6H^5;\ C^2HO). \\ 28]. & ZH^3,C^6H^5; & C^2H^3O^3 + 2(ZH,C^6H^5;\ C^2HO). \end{array}$$

These four salts agree exactly with one another in structure. The only difference among them is, that the basic radical H, in No. 25, is replaced in the other salts by Ag, Ba, and ZH^3,C^6H^5. In every example, the mylite, or single salt with the radical C^2H^3 is a normal salt with O^3, and is accompanied by two atoms of an anile (phenyl-amid) with the acid radical C^2H. These amids have each, of course, only one atom of oxygen, the total quantity of oxygen in each salt being five atoms. Here, therefore, each of the three acid radicals which constitute the citric acid acts precisely as if it were an independent acid radical.

Comparison of No. 28 with No. 23 :—

$$\begin{array}{rr|rr} \text{No. }23]. & ZH^3,C^6H^5;\ C^2H^3O^3 & \text{No. }28]. & ZH^3,C^6H^5;\ C^2H^3O^3. \\ & H;\ C^2H\,O^2 & & ZH\ ,C^6H^5;\ C^2H\,O\ . \\ & H;\ C^2H\,O^2 & & ZH\ ,C^6H^5;\ C^2H\,O\ . \end{array}$$

In No. 28, two atoms of oxygen are deficient because two basic radicals are vice-amids (phenylac). If two atoms of HHO could be combined with No. 28, we should have the tribasic citrate of aniline which has not yet been discovered. If two atoms of HHO could be combined with No. 25, we should have the bibasic citrate of aniline, also at present unknown :

$$\left.\begin{array}{ll} H & ;\ C^2H^3O^3 \\ ZH,C^6H^5 & ;\ C^2H\,O\ + H^2O \\ ZH,C^6H^5 & ;\ C^2H\,O\ + H^2O \end{array}\right\} = \left\{\begin{array}{ll} H & ;\ C^2H^3O^3. \\ ZH^3,C^6H^5 & ;\ C^2H\,O^2. \\ ZH^3,C^6H^5 & ;\ C^2H\,O^2. \end{array}\right.$$

Usual names of these four salts.—No. 25], Citrobianilic acid = $C^{36}H^{18}N^2O^{10}$ = $HO.C^{36}H^{17}N^2O^9$, *Pebal.* Phenyl-citrobiamic acid, *Gerhardt.* Monobasic-citro-monanilate of aniline = $C^{12}H^7N,HO.C^{12}H^5N, C^{12}H^5O^9$, *Fehling.* Aniline salt of monobasic citromonanilic acid = $C^{12}H^7N.HO.C^{24}H^{10}NO^9$, *Pebal.* Hence Pebal gives two entirely different names and formulæ. I do not perceive, from his description, that there is a corresponding difference in the *things.*

Nos. 26, 27, and 28 are Citrobianilates. 26] = $AgO.C^{36}H^{17}N^2O^9$. 27] = $BaO,C^{36}H^{17}N^2O^9$. 28] = $C^{12}H^7N.HO.C^{36}H^{17}N^2O^9$, *Pebal.* According to this chemist, "the composition of these salts shows that the acid is monobasic." (*Quarterly Journal of the Chemical Society*, v. 287.) I cannot agree that citrobianilic acid is shown to be monobasic, because it appears to me that there is no such thing in existence as citrobianilic acid; and once again, I say, that these conjugated acids are a nuisance, alike repugnant to truth and to convenience.

29]. $ZH,C^6H^5;\ C^2H^3O^2 + 2(ZH,C^6H^5;\ C^2HO)$.

Compare Nos. 22 and 29. The latter is the phenylac compound corresponding to the amid compound represented by the former. Compare 29 with 28. There is simply a difference of HHO in one salt; the phenylam mylite of No. 28 is reduced to phenylac mylete in No. 29; the other two salts in each compound remaining the same.

Usual names: Citronanilide = $C^{48}H^{23}N^3O^8$, *Pebal.* Phenyl-citramide = $C^{12}H^8(C^{12}H^5)^3N^3O^8$. Also Triazoture of citryle, of triphenyle, and of hydrogen

$$= N^3 \left\{ \begin{matrix} (C^6H^5)^3 \\ C^6H^5O^4 \\ H^3 \end{matrix} \right\} \textit{Gerhardt.}$$

While Pebal is contented with a clump formula, Gerhardt resorts to the ammonia type, and forces three oxidised salts to appear in the garb of a triple atom of ammonia; a proceeding which is not warranted, and it will be seen, at No. 32, that the ammonia type breaks down when applied to other examples in the citric group.

30]. $ZH,C^6H^5;\ C^2H^3O^2 + Z,C^2H,C^6H^5;\ C^2HO^2$.
31]. $H;\ C^2H^3O^3 + Z,C^2H,C^6H^5;\ C^2HO^2$.
32]. $Ag;\ C^2H^3O^3 + Z,C^2H,C^6H^5;\ C^2HO^2$.

These three salts give important testimony in favour of the theory which I am advocating. Each of the three formulæ is divided into two parts. The first part of No. 30] is an amid similar to the first part of No. 29]. The first part of Nos. 31 and 32 resemble the corresponding parts of Nos. 25 and 26. In these parts of the three salts there is, therefore, nothing peculiar. The interest lies in the second part of the formulæ, which is the same in all three examples, and which represents the compounds that are commonly called *Aniles*, examples of which are given at page 224, and the theory of which has been fully explained in the section that commences at page 222.

The usual names and formulæ of these three salts are as follow:

30]. Citrobianil = $C^{36}H^{16}N^{2}O^{8}$, *Pebal.* Phenyl-citrimide; Citro-bianile, or diazoture of citryle, of diphenyle, and of hydrogen = $C^{18}H^{16}N^{2}O^{4}$

$$= N^{2}\left\{\begin{matrix}(C^{6}H^{5})^{2}\\ C^{6}H^{5}O^{4}\\ H\end{matrix}\right\}, \textit{ Gerhardt.}$$

"Citrobianil may be supposed to be formed from bibasic citrate of aniline by separation of 6HO:

$$\left.\begin{matrix}C^{12}H^{7}N.HO\\ C^{12}H^{7}N.HO\\ HO\end{matrix}\right\}C^{12}H^{5}O^{11} - 6HO = C^{36}H^{16}N^{2}O^{8}.\text{"} \quad \textit{Pebal.}$$

31]. "Monobasic citromonanilic acid = $C^{24}H^{11}NO^{10}$. It may be regarded as monobasic citrate of aniline minus 4HO:

$$\left.\begin{matrix}C^{12}H^{7}N.HO\\ HO\\ HO\end{matrix}\right\}C^{12}H^{5}O^{11} - 4HO = C^{24}H^{11}NO^{10}.\text{"} \quad \textit{Pebal.}$$

32]. The silver salt of monobasic citromonanilic acid = AgO. $C^{24}H^{10}NO^{9}$, *Pebal.*

I cannot find that Gerhardt has anywhere reduced Nos. 31 and 32 to "type ammonia." These salts in fact are such as would require an extreme amount of pressure to fit them to that type; for against one atom of azote we have in 31] the following substitutes for hydrogen: H = 1 atom, $C^{6}H^{5}$ phenyl = 1 atom, $C^{6}H^{5}O^{4}$ citryle = 3 atoms, and O in excess. These atoms will make neither an azoture nor a diazoture, and therefore "type ammonia" breaks down.

Pebal makes no attempt to explain the constitution of these salts. He shows their mode of derivation from normal salts, but concludes in each case with a clump formula and a name drawn from the store-house of conjugated acids, that much-frequented place of refuge for distracted theorists.

Tried in any way, these compounds present great difficulties on the theory that the citrates are tribasic but monacid. We have the following atoms to deal with:

No. 30]. $Z,ZH,C^{6}H^{5},C^{6}H^{5}$; $C^{6}H^{5}O^{4}$.
No. 31]. $ZH,C^{6}H^{5}$; $C^{6}H^{5}O^{5}$.
No. 32]. $ZAg,C^{6}H^{5}$; $C^{6}H^{5}O^{5}$.

Presented in this light, these basic radicals are unintelligible fragments, and the variations in the quantity of oxygen are difficult to be accounted for. The usual theoretical explanation given of salts that contain such fragmentary radicals is, that they are SO-AND-SO *minus* SO-AND-SO. That explanation tells us *how they came to be* what they are, but that is not a sufficient explanation. I want to know *what they are* while they are in the state in which we have them. Gerhardt tries to evade this difficulty by telling us, that the proper definition of a thing is, not what it is, but what it has been, or what it may come to be; an unsatisfactory argument, which I have discussed at page 410.

Now, on the theory that the citrates are triple salts, the formulæ 30, 31, and 32 present no difficulties whatever. We can account, not only for the variations in the quantity of the oxygen, but for every separate radical, and show that it is doing its proper duty. Thus:

$$\left.\begin{array}{r} ZH^3,C^6H^5;\ C^2H^3O^3 \\ ZH^3,C^6H^5;\ C^2H\ O^2 \\ H\ ;\ C^2H^3O^2 \end{array}\right\} = \left\{\begin{array}{l} H^2O \\ H^3O^2 + \\ H^1 \end{array}\begin{array}{r} ZH,C^6H^5;\ C^2H^3O^2 \\ Z\ \ ,C^6H^5;\ C^2H\ \ \ \ \\ ;\ C^2H\ O^2 \end{array}\right\} \text{No. 30.}$$

A citrate containing two atoms of phenylam — Water, 3 atoms. — Residue.

The abstraction of HHO from the first salt simply converts it into an amidogen salt. The abstraction of 2HHO from the other two salts, leaves such a residue as constitutes an *imide* or an *anile*, the theory of which I have fully explained in the article on Imidogen compounds at page 222, to which I have already referred. The azotic radical No. 226, page 224, is the exact counterpart of the second half of the formulæ of Nos. 30, 31, and 32. Thus:

$Z,C^2H^2,C^6H^5;\ C^2H^2O^2$ Succinylic-phenylac succinylete.
$Z,C^2H\ ,C^6H^5;\ C^2H\ O^2$ Dylic-phenylac dylete.

Again, No. 31 requires merely the addition of two atoms of water to be restored to the condition of its normal salt No. 23.

$$\begin{array}{ccc} \left.\underbrace{\begin{array}{r} H;\ C^2H^3O^3 \\ Z,C^6H^5;\ C^2H\ O \\ C^2H\ O \end{array}}_{\text{No. 31}} \begin{array}{c} \\ + H^4O^2 \\ \\ + \text{Water} \end{array}\right\} & = & \left\{\underbrace{\begin{array}{r} ZH^3,C^6H^5;\ C^2H^3O^3 \\ H;\ C^2H\ O^2 \\ H;\ C^2H\ O^2 \end{array}}_{\text{No. 23.}}\right. \end{array}$$

The same quantity of water applied to No. 32 would produce the following salt, which is nearly related to No. 23:

$$ZH^3,C^6H^5;\ C^2H^3O^3 + Ag,C^2HO^2 + H,C^2HO^2.$$

These considerations prove, almost with the force of mathematical demonstration, that the citrates ought to be considered to be triple salts, each having, not only three basic radicals, but also three acid radicals. On that supposition you can account fully for all their reactions and transformations, without the necessity of resorting to conjugated acids, type ammonia, or other cumbersome or rickety hypotheses, contrived to make things pleasant, or serving to mix them into a muddle.

If, on the contrary, you insist that citric acid shall be considered a terbasic acid, I ask you to explain, how it comes to pass, that the citric acid radical C^6H^5 so thoroughly and effectually holds in the majority of cases, all the chemical powers of three separate radicals, and yet frequently suffers their abnegation to such an extent that you cannot dispose of the positive radicals without a reinforcement of six or eight conjugated acids? It is easy to declare off hand that a terbasic acid radical has the powers of three monobasic acid radicals; but when you come to account for the variations in the quantity of oxygen and for the constitution of amides, imides, aniles, conjugated acids, and similar imaginary compounds to which the terbasic doctrine drives you; the difficulties and contradictions which assail you are so unconquerable, that you are driven, in despair, to take shelter behind that convenient dummy—the unitary formula.

INVESTIGATION OF THE ACONITES.

When citric acid is exposed to heat, it disengages carbonic oxide and carbonic acid, and yields a residue which is called Aconitic acid, and which is commonly indicated by the following formula: $3HO,C^{12}H^3O^9$.

"Aconitic acid is isomeric with fumaric and malæic acids. Hydrated aconitic acid contains the elements of two equivalents of water less than hydrated citric acid: $3HO,C^{12}H^3O^9 + 2HO = 3HO,C^{12}H^5O^{11}$. Indeed, aconitic acid derives its principal interest from its close connection with citric acid, and from the light which its composition throws upon some apparent anomalies in relation to the separation of water from the crystallised acid and its salts." *Miller* (*Elem. Chem.* iii. 343).

Doubling the atomic weights of C and O, and re-arranging the formula, we produce $H^3,C^6H^3O^6$. These numbers represent a terbasic acid, but this acid is made terbasic without necessity, and I divide the formula by 3, which leaves H,C^2HO^2. Dr. Miller's remarks respecting the difficulties which depend upon the different degrees of hydration of citric acid, I have disposed of in the Notes to Nos. 1 and 13 of the citrates. The formula to which I have reduced the aconitic acid, H,C^2HO^2, agrees exactly with the formula of the acid which I have in the sections on the Malates and the Citrates called *Hydra dylete*. I cannot undertake to determine whether the radical C^2H = DYL is the radical of the aconites, the malæates, or the fumarates. That must remain for special determination. I have hitherto used the term Dyl to signify C^2H, in order not to prejudge the question. But I shall use the term aconyl in describing the aconites.

The Table of Examples, Nos. 33 to 42, afford sufficient specimens of the different varieties of aconites. No. 33 is the aconitic acid. Nos. 34 and 35 are examples of neutral salts. Nos. 37 and 39 are examples of the triple salts, which probably gave rise to the notion that the aconites were terbasic:

$$K,C^2HO^2 + 2(H,C^2HO^2) = KH^2,C^6H^3O^6.$$

The salts Nos. 36 and 38 afford examples of double aconites. These were procured by Baup by dividing a quantity of acid into two parts, neutralising one part by a base, and then mixing the whole. The crystals were subsequently analysed, and were found to agree with formulæ that lead to Nos. 36 and 38. Gerhardt and Gmelin, prepossessed with the idea that the aconites were undoubtedly terbasic, concluded that Baup's experiments were inexact; but experiments are not necessarily inexact, because their results disagree with a theory which is itself unfounded.

$$40]. \left\{\begin{array}{r} Z,C^2H,C^6H^5\,;\ C^2HO^2 \\ H\ ;\ C^2HO^2 \end{array}\right\}$$

$$41]. \left\{\begin{array}{r} Z,C^2H,C^6H^5\,;\ C^2HO^2 \\ Ag\,;\ C^2HO^2 \end{array}\right\}$$

These salts are precisely like the salts 31 and 32 of the citric series, excepting that they contain only one kind of acid radical, instead of two different acid radicals. The theory of the constitution of these salts is the same as that by which I have explained the citric salts. Gerhardt's name for No. 40 is Phenyl-aconitamic, or aconitanilic acid $= C^{24}H^9NO^8 = C^{12}H^6O^{12} + C^{12}H^7N - 4HO$. No. 41 is the silver salt of that hypothetical conjugated acid.

$$42]. \left\{\begin{array}{l} Z,C^2H,C^6H^5\,;\ C^2HO^2 \\ ZH\qquad ,C^6H^5\,;\ C^2HO \end{array}\right\}$$

This is evidently the combination of an amidogen salt with an imidogen salt (using the current phraseology of Chemistry). Gerhardt calls it Phenyl-aconitimide; aconito-bianile; or diazoture of aconityle, of diphenyle, and of hydrogen. He gives these formulæ: $= C^{36}H^{14}N^2O^6 = C^{12}H^4(C^{12}H^5)^2N^2O^6$; also $C^{18}H^{14}N^2O^3$

$$= N^2 \left\{\begin{array}{l} (C^6H^5)^2 \\ C^6H^3O^3; \\ H \end{array}\right.$$

and the following to explain the origin of the compound:

$$C^{12}H^6O^{12} + 2C^{12}H^7N - 6HO = C^{36}H^{14}N^2O^6.$$

These three phenylac compounds were discovered by Pebal.

On the radical theory, No. 42 is accounted for by the following equation:

$$\left.\begin{array}{r}ZH^3,C^6H^5;\ C^4HO^4\\ ZH^3,C^6H^5;\ C^4HO^4\\ H\ ;\ C^4HO^4\end{array}\right\} = \left\{\begin{array}{l}HHO\ +\ ZH\ ,C^6H^5;\ C^4HO\\ \left\{\begin{array}{l}HHO\\ HHO\end{array}\right\} + Z,C^4H,C^6H^5;\ C^4HO^4\end{array}\right\}$$

These three derivatives from aniline present great difficulties of explanation if we treat aconitic acid as terbasic. What these difficulties are, I have explained at the end of the section on the citrates. On the other hand, if we treat aconitic acid as monobasic, we can account for the constitution of these amids easily and satisfactorily.

I repeat, then, that the formula of aconitic acid is H^r,C^4HO^4, and that it is monobasic. The assumption of the formula $3HO,C^{12}H^3O^9$, and the declaration of the terbasicity of this acid are justified only by the doctrine, that it is easy to convert a monobasic acid into a terbasic acid by tripling the formula. See page 395.

INVESTIGATION OF THE CITRACONATES.

The common formula of the Citraconic acid is $2HO,C^{10}H^4O^6$, and it is esteemed to be BIBASIC. I propose to show that its reactions and transformations are such as indicate that it is a double monobasic salt, having two different acid radicals, and agreeing with the following formula:

$$H,C^6H^3O^4 + H,C^4HO^4.$$

As this acid can be prepared by heating aconitic acid, it is probable that the radical C^4H is aconyl; but as the acid is commonly procured by heating citric acid, and as I do not wish to prejudge the question respecting the identity of these isomeric radicals, I shall, as before, call the radical C^4H *dyl*, while the other radical C^6H^3 shall be called *tryl*. This radical agrees in composition with acryl, the radical of acrolein, and with the radical of the pyruvates. All these radicals are produced by heating other hydrocarbons. They *may be* one and the same thing, but I cannot say that they *are* so, and therefore I use the term *tryl*, as a provisional name for the acid radical C^6H^3, as it occurs in the Citraconates.

Examples of Citraconates are given in the Table, Nos. 43 to 62. As many of these salts present forms of combination which have been already examined minutely, I shall pass over them briefly.

43]. $H,C^6H^3O^4 + H,C^4HO^4$ Hydra trylete cum hydra dylete.

This is the hydrated aconitic acid. Being a double acid, it has two replaceable atoms of hydrogen, and in that sense is truly bibasic; but, as each of these basic radicals is combined with a separate acid radical, the salts are not bibasic in the ordinary sense of that term, but are biacid as well as bibasic. 44]. This is the citraconic anhydride or anhydrous citraconic acid = C^6H^3,C^4HO^3, which agrees precisely with the compound anhydrides described at page 121. 45] and 46] are examples of acid citraconates. 47] and 48] are examples of neutral citraconates. 49] is a compound salt in which one of the constituent salts is tribasic. 50] is the oxychloride of citraconyl; which Gmelin calls Chloropyrocitryl. A moist air converts it into hydrochloric and hydrated citraconic acid:

$$\begin{array}{l} \mathrm{C^3H^3,ClO + H,HO} \\ \mathrm{C^2H\,,ClO + H,HO} \end{array} = \begin{array}{l} \mathrm{H,C^3H^3O^2 + HCl} \\ \mathrm{H,C^2H\,O^2 + HCl} \end{array}$$

The oxychlorides in general have one atom of chlorine and one atom of oxygen with each organic radical. The same proportions occur here. There are two atoms of chlorine and two atoms of oxygen, because there are two organic radicals. 51] is the Citraconimide, formed by the action of heat on the citraconate of ammonia, No. 45]:

$$45]. = \left\{\begin{array}{l} \mathrm{\ \ H\ \ ;\ C^3H^3O^2} \\ \mathrm{ZH^4;\ C^2H\,O^2} \end{array}\right\} = \left\{\begin{array}{l} \mathrm{ZH,C^3H^3;\ \ C^2HO^2\ = 51].} \\ \mathrm{\ \ HHO\ + HHO\ \ = water.} \end{array}\right.$$

52] is called Citraconamide, and also Citraconamic acid. The term Citraconamide is improper, because it implies the amide of the neutral citraconamate of ammonia, which must have this composition:

$$\mathrm{ZH^2,C^2HO^2 + ZH^2,C^3H^3O^2;}$$

whereas No. 52] is the amide of the acid citraconate of ammonia, and therefore the term citraconamic acid is preferable. No. 53] is the barytic salt of that acid. There are similar salts with Pb and Ag instead of Ba. These salts belong to the amidogen acids with compound radicals, group C, page 227. Compare 242 (in that page) with 52, and 246 with 53.

54]. This is the double amidogen salt, formed from the (unknown) neutral citraconate of aniline. Thus:

$$\begin{array}{l} \mathrm{ZH^3,C^6H^5;\ C^3H^3O^2} \\ \mathrm{ZH^3,C^6H^5;\ C^2H\,O^2} \end{array} = \begin{array}{l} \mathrm{ZH,C^6H^5;C^3H^3O + HHO} \\ \mathrm{ZH,C^6H^5;C^2H\,O + HHO.} \end{array}$$

55]. This salt bears the same relation to the acid citraconate of aniline, which 54] bears to the neutral salt, excepting that it is necessarily produced by the abstraction of only one atom of water. Thus:

$$\begin{array}{r} \mathrm{ZH^3,C^6H^5;\ C^3H^3O^2} \\ \mathrm{H\ ;\ C^2H\,O^2} \end{array} = \begin{array}{l} \mathrm{ZH,C^6H^5;\ C^3H^3O + HHO} \\ \mathrm{\qquad\quad H\ ;\ C^2H\,O^2} \end{array}$$

55] belongs to the anilidogen-acids with compound radicals, Group D, page 228. The salts of this class are called acids, only in accordance with Gerhardt's law, that "any substance is an acid which contains hydrogen capable of being replaced by metals by double decomposition."

56] and 57]. These are merely examples of salts corresponding to the imaginary "acid" No. 55.

58]. $\mathrm{Z,C^3H^3,C^6H^5\quad;\ C^2HO^2}$
59]. $\mathrm{Z,C^3H^3,C^6H^4I\ \ ;\ C^2HO^2}$
60]. $\mathrm{Z,C^3H^3,C^6H^3Z^2;\ C^2HO^6}$

No. 58 is an "anile" similar to those described in Group *b*), page **224**. No. 59 is similar to 58, but contains iodic-phenyl instead of normal phenyl. No. 60 is similar, but contains zotenic-phenyl instead of normal phenyl. The presence of two atoms of azote in this vice-radical causes the salt No. 60 to have four atoms of oxygen more than the corresponding salts Nos. 58 and 59. See the account of the iodic and zotic vice-radicals at page 132. No. 58 is derived from the acid citraconate of phenylam by the abstraction of two atoms of HHO. Thus:

$$\begin{matrix} ZH^3,C^6H^5 ;\ C^3H^3O^2 \\ H\ ;\ C^3H\ O^2 \end{matrix} = \begin{matrix} Z,C^3H^3,C^6H^5 ;\ C^3HO^2 \\ HHO + HHO. \end{matrix}$$

61]. This salt is perfectly equivalent to 55, excepting that it contains zotenic-phenyl instead of normal phenyl, and consequently has four additional atoms of oxygen.

62]. The silver-salt of the "acid" 61. This salt is equivalent to 57, excepting that, like its acid, it contains $Z^2 + O^4$ instead of H^2 in the phenylac.

Usual names of these aniline compounds.—54]. Diphenyl-itaconamide, or diazoture of diphenyle and of itaconyle = $C^{17}H^{16}N^2O^2$

$$= N^2 \left\{ \begin{matrix} C^5H^4O^2 \\ (C^6H^5)^2 ; \\ H^2 \end{matrix} \right.$$

also Itaconanilide = $C^{10}H^6(C^{12}H^5)^2N^2O^4$, *Gerhardt*. 55]. Phenyl-itaconamic, or Itaconanilic acid = $C^{22}H^{11}NO^6 = C^{10}H^6(C^{12}H^5)NO^6$, *Gerhardt*. Citraconanilic acid = $HO.C^{22}H^{10}NO^5 = HO.C^{12}H^6N,C^{10}H^4O^5$, *Fehling*. 58]. Phenyl-citraconimide; citraconanile = $C^{22}H^9NO^4 = C^{10}H^4(C^{12}H^5)NO^4$, *Gerhardt*. 59]. Iodophenyl-citraconimide, or Citraconiodanile = $C^{22}H^8INO^4 = C^{10}H^4(C^{12}H^4I)NO^4$, *Gerhardt*. 60]. Dinitrophenyl-citraconimide = $C^{10}H^4(C^{12}H^3(NO^4)^2)NO^4 = C^{22}H^7(NO^4)^2NO^4 = C^{22}H^7N^3O^{12}$, *Gerhardt*. Citraconbinitranil

$$= C^{12} \left\{ \begin{matrix} H^3 \\ 2NO^4 \end{matrix} \right\} N.C^{10}H^4O^4, \textit{ Fehling.}$$

61]. Dinitrophenyl-citraconamic acid = $C^{22}H^9N^3O^{14} = C^{22}H^9(NO^4)^2O^6 = C^{10}H^6(C^{12}H^3(NO^4)^2)NO^6$, *Gerhardt*.

In 55 and 61, we have, according to Gerhardt, two more conjugated acids; for which assumptions there is, as usual, neither evidence nor necessity.

I have treated these complicated compounds (the Citraconates) very briefly, because, as I have mentioned, every form of combination which they exhibit has repeatedly come under our consideration in the preceding pages, and it appears to be useless to repeat explanations and demonstrations with which the reader may reasonably be supposed to be by this time sufficiently acquainted.

The Succinic Group.

I have suggested at page 81 the desirableness of classified Tables of compound radicals, which should exhibit all that are known, and indicate the place and composition of such as are unknown. And at page 79 I have given a Table representing the radicals which constitute the vinyl series.

In that Table I have pointed out a regular series of Acid radicals, which, beginning with formyl = C^1H^1, proceeds by the addition of atoms of vinyl = C^1H^2, one after the other, to form the series C^2H^3, C^3H^5, &c., up to Melissyl = $C^{30}H^{59}$, at which point we reach the limit of known acid radicals of this series.

In the same Table I have described a series of Basic radicals, which, beginning with hydrogen H^1, proceeds by the addition of atoms of vinyl, C^1H^2, one after the other, to form the regular series CH^3, C^2H^5, &c., up to Myricyl = $C^{30}H^{61}$, where the limit of basic radicals of this series hitherto discovered by experiment is again reached.

In the same manner, I now proceed to describe a regular, though only a short, series of acid radicals, which we may conceive to be formed by commencing with a single atom of carbon = C^1, and adding to it, one by one, a succession of atoms of vinyl = C^1H^2. We thus produce a series of acid radicals, which are all necessarily distinguished by having an even number of atoms of hydrogen, in which respect they differ essentially from the radicals of the vinyl series, all of which contain an uneven number of atoms of hydrogen:

$C + CH^2 = C^2H^2$ = Succinyl.
$C + 2CH^2 = C^3H^4$ = Adipyl.
$C + 3CH^2 = C^4H^6$ = Suberyl.
$C + 4CH^2 = C^5H^8$ = Sebamyl.

This is the limit of the series as far as it is known at present. These radicals produce the following monobasic acids, each with two atoms of oxygen:

		Common Names.
$H,C^2H^2O^2$	= Hydra succinylete . .	Succinic acid.
$H,C^3H^4O^2$	= Hydra adipylete . .	Adipic acid.
$H,C^4H^6O^2$	= Hydra suberylete . .	Suberic acid.
$H,C^5H^8O^2$	= Hydra sebamylete . .	Sebacic acid.

These acids, and all their salts, have the faculty of forming intermediate double salts, and thus produce the following series:

		Common Names.
$\left\{\begin{matrix} H,C^2H^2O^2 \\ H,C^3H^4O^2 \end{matrix}\right\}$	Hydra succinylete cum hydra adipylete.	Pyrotartaric acid.

		Common Names.
$\mathrm{H,C^3H^4O^2}$ $\mathrm{H,C^4H^6O^2}$	Hydra adipylete cum hydra suberylete.	Pimelic acid.
$\mathrm{H,C^4H^6O^2}$ $\mathrm{H,C^5H^8O^2}$	Hydra suberylete cum hydra sebamylete.	Anchoic acid.

These seven acids are commonly assumed to be *Bibasic*, but, making a distinction between bibasic salts and double salts, I deny that there is any evidence to sustain this bibasic character. I shall show, that the first four acids are decidedly monobasic, that the last three are double acids, which act precisely as if each contained two separate acid radicals, and that the supposition that they contain special bibasic radicals is erroneous.

Before I proceed to the examination of these acids individually, I will refer to the relations which they bear to certain acids of the vinyl series:

$$\mathrm{H,C^4H^7O^2 + O^3 - H,HO = H,C^2H^2O^2 + H,C^2H^2O^2}$$
Butyric acid. Succinic acid, 2 atoms.

$$\mathrm{H,C^5H^9O^2 + O^3 - H,HO = H,C^2H^2O^2 + H,C^3H^4O^2}$$
Valerianic acid. Pyrotartaric acid, 1 atom.

$$\mathrm{H,C^6H^{11}O^2 + O^3 - H,HO = H,C^3H^4O^2 + H,C^3H^4O^2}$$
Caproic acid. Adipic acid, 2 atoms.

$$\mathrm{H,C^7H^{13}O^2 + O^3 - H,HO = H,C^3H^4O^2 + H,C^4H^6O^2}$$
Œnanthylic acid. Pimelic acid, 1 atom.

$$\mathrm{H,C^8H^{15}O^2 + O^3 - H,HO = H,C^4H^6O^2 + H,C^4H^6O^2}$$
Caprylic acid. Suberic acid, 2 atoms.

$$\mathrm{H,C^9H^{17}O^2 + O^3 - H,HO = H,C^4H^6O^2 + H,C^5H^8O^2}$$
Pelargonic acid. Anchoic acid, 1 atom.

$$\mathrm{H,C^{10}H^{19}O^2 + O^3 - H,HO = H,C^5H^8O^2 + H,C^5H^8O^2}$$
Rutic acid. Sebacic acid, 2 atoms.

According to this Table, when a volatile acid of the vinyl series is decomposed by 3 atoms of oxygen, one atom of water = HHO separates, and the residue forms two complete acids of the succinic group. Experiment confirms this theoretical view in frequent cases; the acids with an even number of atoms of hydrogen being often produced when the acids of the vinyl series are heated with nitric acid. So, inversely, when the acids of the succinic group are heated alone, they give off carbonic acid = $\mathrm{CO^2}$, and produce volatile acids of the vinyl group.

The succinic group of acids is sometimes called the oxalic acid group, and it is made to commence with the radical C, and the acid $\mathrm{H,CO^2}$ = hydra carbete or hydrated oxalic acid.

Placing that acid = $\mathrm{H,CO^2}$, before succinic acid = $\mathrm{H,C^2H^2O^2}$, we might expect to find the intermediate double acid:—

$$\left\{\begin{matrix}H,C\ \ O^2\\ H,C^2H^2O^2\end{matrix}\right\}\text{Hydra carbete cum hydra succinylete,}$$

but no bibasic acid of this composition has hitherto been observed.

Table of Examples of the Succinic Group.

A. THE SUCCINATES.

1.	$H\ ,C^2H^2O^2$	Hydra succinylete.
2.	$C^2H^2,C^2H^2O^3$	Succinyla succinylite.
3.	$\left\{\begin{matrix}2(H\ ,C^2H^2O^2)\\ C^2H^2,C^2H^2O^3\end{matrix}\right\}$	Bis hydra succinylete cum succinyla succinylite.
4.	$K\ ,C^2H^2O^2$	Potassa succinylete.
5.	$\left\{\begin{matrix}K\ ,C^2H^2O^2\\ H\ ,C^2H^2O^2\end{matrix}\right\}$	Potassa succinylete cum hydra succinylete.
6.	$\left\{\begin{matrix}K\ ,C^2H^2O^2\\ 3(H\ ,C^2H^2O^2\end{matrix}\right\}$	Potassa succinylete tris hydra succinylete.
7.	$ZH^4,C^2H^2O^2$	Ammona succinylete.
8.	$\left\{\begin{matrix}ZH^4,C^2H^2O^2\\ H\ ,C^2H^2O^2\end{matrix}\right\}$	Ammona succinylete cum hydra succinylete.
9.	$Ag,C^2H^2O^2$	Argenta succinylete.
10.	$C\ H^3,C^2H^2O^2$	Methyla succinylete.
11.	$C^2H^5,C^2H^2O^2$	Ethyla succinylete.
12.	$\left\{\begin{matrix}K\ ,C^2H^2O^2\\ Mg\ ,C^2H^2O^2\end{matrix}\right\}$	Potassa succinylete cum magna succinylete.
13.	$Mg^3,C^2H^2O^3$	Magnine succinylite.

Azotic Compounds of Group A.

14.	ZH^2,C^2H^2O	Amida succinylate.
15.	$ZH,C^6H^5\ ;\ C^2H^2O$ . .	Phenylac succinylate.
16.	$\left\{\begin{matrix}ZH^2,C^2H^2O\\ H\ ,C^2H^2O^2\end{matrix}\right\}$ . . .	Hydra amida succinylenite.
17.	$\left\{\begin{matrix}ZH^2,C^2H^2O\\ Ag,C^2H^2O^2\end{matrix}\right\}$ . . .	Argenta amida succinylenite.
18.	$\left\{\begin{matrix}ZH,C^6H^5\ ;\ C^2H^2O\\ H\ ;\ C^2H^2O^2\end{matrix}\right\}$.	Hydra phenylac succinylenite.
19.	$\left\{\begin{matrix}ZH,C^6H^5\ ;\ C^2H^2O\\ Ag\ ;\ C^2H^2O^2\end{matrix}\right\}$.	Argenta phenylac succinylenite.
20.	$ZH,C^2H^2\ ;\ C^2H^2O^2$.	Succinylac succinylete.
21.	$ZAg,C^2H^2\ ;\ C^2H^2O^2$.	Argentic-succinylac succinylete.
22.	$ZC^2H^2,C^6H^5\ ;\ C^2H^2O^2$.	Succinylic-phenylac succinylete.
23.	$\left\{\begin{matrix}ZH^2\ \ ;\ C^2H^2O\\ ZHAg\ ;\ C^2H^2O\end{matrix}\right\}$ . .	Amida succinylate cum argentac succinylate.

Chlorine Compounds of Group A.

24.	C^2H^2,ClO	Succinyla chlorate.
25.	$H,C^2Cl^2O^2$	Hydra chlorenic-succinylete.
26.	$K,C^2Cl^2O^2$	Potassa chlorenic-succinylete.
27.	$C^2Cl^5,C^2Cl^2O^2$	Chlorunic-ethyla chlorenic-succinylete.

Sulpho-succinates.

28.	$\left\{\begin{matrix} H,C^2H^2O^2 \\ H,SO^2 \end{matrix}\right\}$	Hydra succinylete cum hydra sulphete.
29.	$\left\{\begin{matrix} C^2H^2,C^2H^2O^3 \\ 2(H,SO^2) \end{matrix}\right\}$	Succinyla succinylite bis hydra sulphete.
30.	$\left\{\begin{matrix} ZH^4,C^2H^2O^2 \\ H\ ,C^2H^2O^2 \\ 2(ZH^4,SO^2) \end{matrix}\right\}$	Ammona succinylete cum hydra succinylete bis ammona sulphete.
31.	$\left\{\begin{matrix} K\ ,C^2H^2O^2 \\ H\ ,C^2H^2O^2 \\ 2(K,SO^2) \end{matrix}\right\}$	Potassa succinylete cum hydra succinylete bis potassa sulphete.
32.	$\left\{\begin{matrix} Pb,C^2H^2O^2 \\ H\ ,C^2H^2O^2 \\ 2(Pb,SO^2) \end{matrix}\right\}$	Plumba succinylete cum hydra succinylete bis plumba sulphete.
33.	$\left\{\begin{matrix} H\ ,C^2H^2O^2 \\ K\ ,SO^2 \end{matrix}\right\}$	Hydra succinylete cum potassa sulphete.
34.	$\left\{\begin{matrix} Pb,C^2H^2O^2 \\ Pb,SO^2 \end{matrix}\right\}$	Plumba succinylete cum plumba sulphete.
35.	$\left\{\begin{matrix} C^2H^2,C^2H^2O^3 \\ 2(Ca,SO^2) \end{matrix}\right\}$	Succinyla succinylite bis calca sulphete.
36.	$\left\{\begin{matrix} C^2HBa,C^2H^2O^3 \\ 2(Ba,SO^2) \end{matrix}\right\}$	Barytic-succinyla succinylite bis baryta sulphete.

B. THE ADIPATES.

37.	$H\ ,C^3H^4O^2$	Hydra adipylete.
38.	$Ca\ ,C^3H^4O^2$	Calca adipylete.
39.	$Ag\ ,C^3H^4O^2$	Argenta adipylete.
40.	$C^2H^5,C^3H^4O^2$	Ethyla adipylete.

C. THE SUBERATES.

41.	$H\ ,C^4H^6O^2$	Hydra suberylete.
42.	$ZH^4,C^4H^6O^2$	Ammona suberylete.
43.	$Ag\ ,C^4H^6O^2$	Argenta suberylete.
44.	$Pb\ ,C^4H^6O^2$	Plumba suberylete.
45.	$\left\{\begin{matrix} Pb^3,C^4H^6O^3 \\ Pb\ ,C^4H^6O^2 \end{matrix}\right\}$	Plumbine suberylite cum plumba suberylete.
46.	$C\ H^3,C^4H^6O^2$	Methyla suberylete.

47.	$C^2H^5,C^4H^6O^2$	Ethyla suberylete.
48.	ZH^2,C^4H^6O	Amida suberylate.
49.	$ZH ,C^6H^5 ; C^4H^6O$	Phenylac suberylate.
50.	ZH ,C^6H^5 , C^4H^6O $H ; C^4H^6O^2$	Hydra phenylac suberylenite.
51.	$ZH ,C^6H^5 ; C^4H^6O$ $Ag ; C^4H^6O^2$	Argenta phenylac suberylenite.

D. THE SEBATES.

52.	$H ,C^5H^8O^2$	Hydra sebamylete.
53.	$K ,C^5H^8O^2$	Potassa sebamylete.
54.	$Ag ,C^5H^8O^2$	Argenta sebamylete.
55.	$C H^3,C^5H^8O^2$	Methyla sebamylete.
56.	$C^2H^5,C^5H^8O^2$	Ethyla sebamylete.
57.	ZH^2,C^5H^8O	Amida sebamylate.
58.	ZH^2,C^5H^8O $H ,C^5H^8O^2$	Hydra amida sebamylenite.
59.	$H,H,C^3H^5 ; C^5H^8O^4$	Hydren glycyla sebamylote.

E. THE PYROTARTRATES.

60.	$H ,C^3H^4O^2$ $H ,C^2H^2O^2$	Hydra adipylete cum hydra succinylete.
61.	$C^3H^4,C^2H^2O^3$	Adipyla succinylite.
62.	$ZH^4,C^3H^4O^2$ $ZH^4,C^2H^2O^2$	Ammona adipylete cum ammona succinylete.
63.	$ZH^4,C^3H^4O^2$ $H ,C^2H^2O^2$	Ammona adipylete cum hydra succinylete.
64.	$Ba ,C^3H^4O^2$ $Ba ,O^2H^2O^2$	Baryta adipylete cum baryta succinylete.
65.	$Ba ,C^3H^4O^2$ $H ,C^2H^2O^2$	Baryta adipylete cum hydra succinylete.
66.	$Pb ,C^3H^4O^2$ $Pb ,C^2H^2O^2$	Plumba adipylete cum plumba succinylete.
67.	$Pb^3,C^3H^4O^3$ $Pb ,C^2H^2O^2$	Plumbine adipylite cum plumba succinylete.
68.	$Pb^3,C^3H^4O^3$ $Pb^3,C^2H^2O^3$	Plumbine adipylite cum plumbine succinylite.
69.	$C H^3,C^3H^4O^2$ $C H^3,C^2H^2O^2$	Methyla adipylete cum methyla succinylete.
70.	$C^2H^5,C^3H^4O^2$ $C^2H^5,C^2H^2O^2$	Ethyla adipylete cum ethyla succinylete.
71.	$Alc^3,C^3H^4O^3$ $H^3,C^2H^2O^3$	Alinic adipylite cum hydrine succinylite.

72.	$\left\{\begin{matrix} Bic^3\ ,C^3H^4O^3 \\ BicH^3,C^2H^2O^3 \end{matrix}\right\}$	Bisminic adipylite cum bismic hydren succinylite.
73.	$\left\{\begin{matrix} Uc^3\ ,C^3H^4O^3 \\ Uc\,H^2,C^2H^2O^3 \end{matrix}\right\}$	Urinic adipylite cum uric hydren succinylite.

Azotic Compounds of Group E.

74.	$ZH,C^3H^4;\ C^2H^2O^2$ . . .	Adipylac succinylete.
75.	$Z,C^3H^4,C^6H^5;\ C^2H^2O^2$.	Adipylic-phenylac succinylete.
76.	$Z,C^3H^4,C^6H^4Z;\ C^2H^2O^4$.	Adipylic-zotic-phenylac succinylote.
77.	$\left\{\begin{matrix} ZH,C^6H^5 & ;\ C^3H^4O \\ H & ;\ C^2H^2O^2 \end{matrix}\right\}$.	Phenylac adipylate cum hydra succinylete.
78.	$\left\{\begin{matrix} ZH,C^6H^5 & ;\ C^3H^4O \\ Pb & ;\ C^2H^2O^2 \end{matrix}\right\}$.	Phenylac adipylate cum plumba succinylete.
79.	$\left\{\begin{matrix} ZH,C^6H^4Z & ;\ C^3H^4O^3 \\ H & ;\ C^2H^2O^2 \end{matrix}\right\}$.	Zotic-phenylac adipylite cum hydra succinylete.

F. The Pimelates.

80.	$\left\{\begin{matrix} H\ ,C^4H^6O^2 \\ H\ ,C^3H^4O^2 \end{matrix}\right\}$.	Hydra suberylete cum hydra adipylete.
81	$\left\{\begin{matrix} Ag,C^4H^6O^2 \\ Ag,C^3H^4O^2 \end{matrix}\right\}$.	Argenta suberylete cum argenta adipylete.

G. The Anchoates.

82.	$\left\{\begin{matrix} H\ ,C^5H^8O^2 \\ H\ ,C^4H^6O^2 \end{matrix}\right\}$.	Hydra sebamylete cum hydra suberylete.
83.	$\left\{\begin{matrix} Ag,C^5H^8O^2 \\ Ag,C^4H^6O^2 \end{matrix}\right\}$.	Argenta sebamylete cum argenta suberylete.
84.	$\left\{\begin{matrix} Ba\ ,C^5H^8O^2 \\ Ba\ ,C^4H^6O^2 \end{matrix}\right\}$.	Baryta sebamylete cum baryta suberylete.
85.	$\left\{\begin{matrix} K\ ,C^5H^8O^2 \\ H\ ,C^4H^6O^2 \end{matrix}\right\}$.	Potassa sebamylete cum hydra suberylete.

Investigation of the Succinic Group of Salts.

The Succinates, Group A. Nos. 1 to 36.

1].	$H,C^2H^2O^2$	Hydra succinylete.
2].	$C^2H^2,C^2H^2O^3$	Succinyla succinylite.
3].	$2(H,C^4H^2O^2)+C^2H^2,C^2H^2O^3$	Bis hydra succinylete cum succinyla succinylite.

These three salts represent succinic acid. No. 1] is the crystallised acid. No. 2] is the anhydrous acid. No. 3] is the sublimed acid, which contains two atoms of the hydrated acid, and one atom of the anhydride, or in all, four atoms of the radical succinyl.

Gerhardt doubles the formula of succinic acid, and calls it BIBASIC; many organic chemists imitate him; but the practice is unnecessary, and the consequences are more injurious than beneficial. All the salts can be perfectly well accounted for on the supposition that succinyl is monobasic, and agrees with the formula C^2H^2. This radical has no atomic measure in gaseous salts. See page 96.

$$\begin{array}{ll|ll} 4]. & K\ ,C^2H^2O^2 & 10]. & CH^3,C^2H^2O^2 \\ 7]. & ZH^4,C^2H^2O^2 & 11]. & C^2H^5,C^2H^2O^2. \\ 9]. & Ag\ ,C^2H^2O^2 & & \end{array}$$

These five salts are examples of neutral monobasic succinates.

$$5].\left\{\begin{array}{l} K,C^2H^2O^2 \\ H,C^2H^2O^2 \end{array}\right. \quad\Bigg|\quad 8].\left\{\begin{array}{l} ZH^4,C^2H^2O^2 \\ \ \ H\ ,C^2H^2O^2 \end{array}\right. \quad\Bigg|\quad 12].\left\{\begin{array}{l} \ K\ ,C^2H^2O^2 \\ Mg,C^2H^2O^2 \end{array}\right.$$

These are examples of double salts, of similar constitution to the double sulphates (page 150) and double oxalates (page 179).

$$6].\ K,C^2H^2O^2 + 3(H,C^2H^2O^2).$$

A quadruple salt, equivalent to the quadroxalate of potash (page 179).

$$13].\ Mg^3,C^2H^2O^3 = Mg,C^2H^2O^2 + Mg,MgO.$$

A terbasic succinate, similar in structure to the terbasic phosphates and other salts of this character, which have been frequently explained in the preceding pages.

Succinates with Azotic Radicals, Nos. 14 to 23.

The salts of this group present forms of combination which have been so frequently quoted and criticised, that it seems to be scarcely necessary to go through their investigation individually. No. 14] is Succinamide, derived from the neutral ammonium salt No. 7. No. 15] Succinanilide, corresponding to No. 14, but containing phenylac instead of normal amid. 16]. Succinamic acid. See No. 245, page 227. 17]. A salt of the acid No. 16. 18]. Succinanilic acid. See No. 250, page 228. 19]. A salt of the acid No. 18. 20]. Succinimide; see No. 221, page 224. 21]. Succinimide, in which H^1 is replaced by Ag^1. 22]. Succinanile; No. 226, page 225. 23]. A double atom of succinamide, in which one of the atoms of ZH^2 has been replaced by ZHAg. The salts of this group have been thoroughly investigated in the Theory of the Azotic Radicals, particularly between pages 222 and 228.

Chlorine Compounds of Group A, Nos. 24 to 27.

24]. The oxychloride of succinyl. 25]. Succinic acid, in which all the hydrogen of the acid radical is replaced by chlorine. 26]. Potash salt of the chlorinated acid No. 25. 27]. Succinate of ethyl, No. 11, in which all the hydrogen, both of the succinyl and the ethyl, is replaced by chlorine.

The Sulpho-succinates, Nos. 28 to 36.

It is stated in most chemical works that the sulpho-succinates contain a compound acid, the sulpho-succinic acid, which is composed of sulphuric acid and succinic acid, and which is TERBASIC. Gerhardt's formulæ for it are as follow:

$C^8H^6S^2O^{14} + 2$ aq. $= C^8H^6O^8,2SO^3 + 2$ aq. (*Traité de Chimie*, ii. 470), and $C^4H^6SO^7 = O^3 \left\{\begin{matrix} C^4H^3(SO^2)O^2 \\ H^3 \end{matrix}\right.$, (*Traité*, iv. 611). Miller's formula is $3HO,C^8H^3O^5,2SO^3$, 2 aq. I am unable, however, to find any evidence to prove the existence of this compound or conjugated terbasic acid, and it appears to be far more probable that the salts are compounds of succinates with sulphates, sometimes neutral and sometimes with excess of acid. The formulæ Nos. 28 to 36, are framed in accordance with this opinion.

$$28].\ H,C^2H^2O^2 + H,SO^2.$$

A double salt containing one atom each of hydrated succinic acid and hydrated sulphuric acid. These proportions agree with Miller's formula and with Gerhardt's first formula. It is a double acid, and not a single bibasic acid with a compound radical.

$$29].\ C^2H^2,C^2H^2O^3 + 2(H,SO^2).$$

This compound agrees with Gerhardt's second formula. It is the acid which is assumed to be formed by the action of anhydrous sulphuric acid upon hydrated succinic acid; thus:

$$\left.\begin{matrix} H,C^2H^2O^2 \\ H,C^2H^2O^2 \\ S\ ,SO^3 \end{matrix}\right\} = \left\{\begin{matrix} C^2H^2,C^2H^2O^3 \\ H,SO^2 \\ H,SO^2 \end{matrix}\right.$$

The acid 29] is equivalent to two atoms of the acid 28], less one equivalent of HHO. It is half in the hydrated condition, and half in the condition of anhydride.

$$30].\ \left\{\begin{matrix} H\ ,C^2H^2O^2 + ZH^4,SO^2 \\ ZH^4,C^2H^2O^2 + ZH^4,SO^2 \end{matrix}\right\}$$

$$31.]\ \left\{\begin{matrix} H\ ,C^2H^2O^2 + K\ ,SO^2 \\ K\ ,C^2H^2O^2 + K\ ,SO^2 \end{matrix}\right\}$$

$$32].\ \left\{\begin{matrix} H\ ,C^2H^2O^2 + Pb\ ,SO^2 \\ Pb\ ,C^2H^2O^2 + Pb\ ,SO^2 \end{matrix}\right\}$$

These three compounds afford examples of the salts that are commonly called *terbasic* sulpho-succinates. There are, indeed, three metallic radicals in each of these examples, but there is also in each one atom of basic hydrogen, which makes the salts *tetrabasic*. There is no proof that this atom of hydrogen forms a conjugated acid with the sulphur and the succinyl. On the contrary, the salts are evidently double salts of the form of the hydrated acid No. 28, and are therefore tetra-acid as well as tetra-basic, or, in other words, are quadruple salts.

$$33].\ H,C^2H^2O^2 + K,SO^2.$$

This salt is produced by mixing a solution of No. 31 with a solution of No. 28. This is the simplest form of the *acid salt* of the series. It resembles one-half of each of the double salts Nos. 30, 31, and 32.

$$34].\ Pb,C^2H^2O^2 + Pb,SO^2.$$

This is the form of the *neutral salt* of the series, and it resembles the second half of each salt of the series of double salts, Nos. 30, 31, 32. That is to say, those three double salts result from the combination in pairs of salts of the forms shown by Nos. 33 and 34.

When the salt No. 34 is dried, it loses water, and falls into the compound shown by the following formula:

$$C^2HPb,C^2HPbO^3 + 2(Pb,SO^2),\ \textit{Fehling}.$$

In this case the radical succinyl C^2H^2 is converted into the metallic vice-radical *Plumbic-succinyl* $\underset{-}{C}^2H\dot{P}b$.

$$35].\ C^2H^2,C^2H^2O^3 + 2(Ca,SO^2).$$

This compound represents the semi-anhydride No. 29, with its basic hydrogen replaced by calcium. The formula represents the salt after it is dried at 212° F. When in solution, it has an acid reaction, and probably has then the constitution represented by formula 33, viz.: $H,C^2H^2O^2 + CaSO^2$; because

$$\left\{\begin{array}{l} C^2\,H^2,C^2H^2O^3 + 2(Ca,SO^2) \\ +H\,,\quad H\,O \end{array}\right\} = \left\{\begin{array}{l} H,C^2H^2O^2 + CaSO^2 \\ H,C^2H^2O^2 + CaSO^2 \end{array}\right\}$$

$$36].\ C^2HBa,C^2H^2O^3 + 2(Ba,SO^2).$$

This salt contains barytic-succinyl C^2HBa. The formula represents the composition of the salt dried at 212° F. If dried less, so as to contain HHO more, its composition would be equal to that of the salt 32, namely:

$$\left\{\begin{array}{l} H\,,C^2H^2O^2 + Ba,SO^2 \\ Ba,C^2H^2O^2 + Ba,SO^2. \end{array}\right\}$$

No. 36 is the only salt of the series which warrants the common assumption, that the sulpho-succinates contain three atoms of H in the acid, and three atoms of H replaceable by basic radicals. It is, nevertheless, an exceptional, and not a normal, form of the sulpho-succinates.

There is a remarkable diversity in the constitution of the salts of this acid, arising from the facility with which it gives off successive quantities of HHO during the process of drying; but, notwithstanding this diversity, we perceive nowhere any symptoms of the existence of a conjugated acid radical composed of succinyl and sulphur. I conclude, therefore, that the sulpho-succinates are double salts composed of sulphates and succinates, combined together, either in their normal condition, or in various states of dehydration.

THE ADIPATES. GROUP B. Nos. 37 to 40.

Professor Miller's formula for adipic acid is $2HO,C^{12}H^8O^6$. Correcting the atomic weights of C and O, and dividing the whole formula by 2, we produce $H,C^3H^4O^2$, which agrees with No. 37. No compound of adipic acid is known, which warrants the doubling of the formula to make the monobasic acid appear to be bibasic.

THE SUBERATES. GROUP C. Nos. 41 to 51.

The formula commonly given to suberic acid is $2HO,C^{16}H^{12}O^6$, which represents it to be bibasic. After correcting the weights of C and O, and reducing the formula to the monobasic form, we have $H,C^4H^6O^2$, which agrees with No. 41. There are no bibasic suberates. No. 45 is a tetrabasic salt of similar structure to the pyrophosphates. The amidogen salts are perfectly regular, and prove this acid to be monobasic. No. 48 is suberamid, evidently derived, in the usual way, from the neutral ammonium salt No. 42 by the abstraction of HHO. No. 49 is the corresponding anilide, differing from No. 48, only by the replacement of amidogen ZH^2, by phenylac ZH,C^6H^5. Gerhardt's names and formula for this salt are as follow :—

$$\left.\begin{array}{r}\text{Diphenyl-suberamide, or}\\ \text{suberanilide.}\\ \textit{Traité}\text{, ii. 734.}\end{array}\right\}\begin{array}{c}C^{40}H^{24}N^2O^4\\ =N^2H^2(C^{12}H^5)^2(C^8H^6O^2)^2\end{array}$$

$$\left.\begin{array}{r}\text{Diazoture of diphenyle}\\ \text{and of suberyle.}\\ \textit{Traité}\text{, iv. 778.}\end{array}\right\}\begin{array}{l}\quad C^{20}H^{24}N^2O^4\\ =N^2\left\{\begin{array}{c}C^8H^{12}O^2\\ ({}^6H^5)^2\\ H^2\end{array}\right.\end{array}$$

By comparing these four formulæ with No. 49 (ZH,C^6H^5; C^4H^6O), the reader will perceive how much he gains in knowledge and convenience by doubling the formula to make the acid bibasic, and how much by throwing it into the form of the ammonia type.

No. 50 is one of the so-called anilidogen acids, Gerhardt's name and formula for which are as follow :—

$$\left.\begin{array}{r}\text{Phenyl-suberamic or}\\ \text{suberanilic acid.}\\ \textit{Traité}\text{, ii. 735.}\end{array}\right\}\begin{array}{c}C^{28}H^{19}NO^6\\ =\left.\begin{array}{r}NH(C^{12}H^5)(C^8H^6O^2)^2O\\ HO\end{array}\right\}\end{array}$$

Here we have a formula on the model of water, according to which we are required to believe that the radical nitrogen = N, the radical hydrogen = H, the radical phenyl = C^6H^5, two atoms of the radical suberyl, each = C^4H^6, and two atoms of oxygen = O^2, are all compressed into a single conjugated radical which is the equivalent of one atom of hydrogen = H^1. Gracious goodness, how these organic chemists speculate upon our credulity!

Hofmann's formula for No. 50 is $H,C^8H^6O^4$; $C^{12}H^6N,C^8H^6O^2$.

51. This is the silver salt of the "acid" No. 50.

THE SEBATES. GROUP D. Nos. 52 to 59.

The common formula of sebacic acid is $2HO,C^{20}H^{16}O^6$. After correcting the weights of C and O, and dividing the formula by 2 to bring it down to the monobasic standard, we have $H,C^5H^8O^2$, which agrees with No. 52. All the salts, Nos. 53 to 59, agree with the assumption that sebacic acid is monobasic. In Nos. 52 to 56, the quantity of oxygen is O^2. In the rest, it differs. No. 57 is sebamide, and has, therefore, only one atom of oxygen. No. 58 is sebamic acid, already quoted at page 227. It possesses O^3. No. 59 is the compound of glycerine and sebacic acid, which Berthelot calls *sebacine*. I have quoted it at No. 11, page 374. In that case, I have represented glycyl, and in this case sebamyl, as the acid radical. That is of little moment, as these radicals are nearly equivalent to each other. The salt No. 59 contains 4 atoms of oxygen, namely O^4, because the normal glycylates (allylates?) and the normal sebates both require that quantity of oxygen; O^1 extra because the salt contains an acid radical acting as a basic radical; and an additional O^1 because the salt is terbasic. Consequently the O^4 are essential. Professor Miller gives for this salt, Berthelot's unitary formula of $C^{32}H^{30}O^{16}$, which affords a good example of the utter worthlessness of unitary formulæ in organic chemistry. These gentlemen have the help of the theory, that sebacic acid is bibasic. They have the help of the theory, that glycerine is teratomic, and therefore requires three acids, or three atoms of acid, to neutralise it. Yet, with these helps, they cannot get beyond a unitary formula to describe the constitution of the sebate of glycerine, and in that unitary formula they represent as many ultimate atoms as would make nearly three atoms of sebacine instead of one. Even after correcting the atomic weights of C and O, the quantities of every element are double what they ought to be. In that way only is it, that the sebates can be made to appear to be bibasic.

THE PYROTARTRATES. GROUP E. Nos. 60 to 79.

I consider a pyrotartrate to contain an adipate in combination with a succinate. Thus:—

$$\left.\begin{array}{l}\text{No. 1} = H,C^2H^2O^2\\ \text{No. 37} = H,C^3H^4O^2\end{array}\right\} = \text{No. 60}\left\{\begin{array}{l}H,C^2H^2O^2\\ H,C^3H^4O^2\end{array}\right.$$

The pyrotartrates are truly bibasic, but they are also biacid. They contain two basic radicals; they also contain two acid radicals; and these two acid radicals are succinyl C^2H^2 and adipyl C^3H^4. There is no evidence to prove that these salts are bibasic with a single acid radical. All the facts show, that two acid radicals are present in each salt. The azotic compounds, Nos. 74 to 79, are intelligible only on that supposition. I consider it needless to examine the salts individually. A glance at the list of examples instantly supplies abundant evidence of the justness of these assumptions. Every salt contains two atoms of basic hydrogen, which may be replaced together or separately. If both are replaced, we have a neutral salt, Nos. 62, 64, 66, 69, 70. If only one is replaced, we have an acid salt, Nos. 63 and 65.

In No. 61 we have the pyrotartaric anhydride. Represented as consisting of two radicals $C^3H^4 + C^2H^2 + O^3$, this salt is intelligible, and the formula agrees with that of all the other anhydrides; but if we represent it as containing only one radical $C^5H^6 + O^3$, it disagrees with every anhydride that has been spoken of in the preceding pages, and we have, without necessity, and to accomplish no good end, to inaugurate a new class of anhydrous acids. That is a course of proceeding which the law of simplicity forbids. We do not require another class of anhydrides; we can do very well with one class; and the evidence is not in favour of, but strongly against, the existence of the supposed radical C^5H^6. I therefore adhere to formula 61.

TERBASIC PYROTARTRATES.—In Nos. 67, 68, 71, 72, and 73, we have examples of terbasic salts. The usual formulæ of these salts are very complicated, but, for brevity sake, I forbear to quote them; particularly as a discussion upon them would not illustrate the particular point which is now under consideration, which is, the biacid nature of the pyrotartaric acid. In each of these terbasic salts, there is an addition of oxygen corresponding to the additional quantity of basic radicals.

PYROTARTRATES WITH AMIDOGEN BASES.—The salts, Nos. 74 to 99, prove decidedly, that pyrotartaric acid contains two acid radicals. Upon that supposition, these six salts are quite regular. Upon the supposition that only one acid radical is present, the formulæ of these salts present clumsy improbabilities. In this case I must go a little into detail.

74]. $ZH,C^3H^4;\ C^2H^2O^2$.

Gerhardt's name and formula for this salt are as follow: Pyrotartrimide, or azoture of pyrotartryl and of hydrogen

$$C^5H^7NO^2 = N\left\{\begin{array}{c}C^5H^6O^2\\ H\end{array}\right. .$$

Of course, Gerhardt considers $C^5H^6O^2$ to be the equivalent of H^2, and so it is; not, however, because H^2 is necessary to complete an ammonia, but because C^3H^4 is equal to H^1, and C^2H^2 is equal to another H^1. The amidogen salt, No. 74, is derived from the unknown normal ammonium salt $ZH^3,C^3H^4;\ C^2H^2O^3$. There is O^3 in this normal salt, because the basic radical contains an acid radical; otherwise the salt produced by the acid radical C^2H^2 would require only O^2. Hence the amidogen salt No. 74 contains O^2, and the pyrotartaric radical is evidently separable into the acid radical C^2H^2 and the radical C^3H^4, which forms part of the vice-amidogen. If we disregard the ammonia type, and write the salt with Gerhardt's radicals, thus: $ZH;\ C^5H^6O^2$, we have a salt with an *imidogen* base, the existence of which appears to me to be impossible, for reasons which I have assigned in the article on the imidogens, commencing at page 222.

75]. $Z,C^3H^4,C^6H^5;\ C^2H^2O^2$.

Gerhardt's phenyl-pyrotartrimide, or pyrotartranile $= C^{10}H^6(C^{12}H^5)NO^4 = C^{22}H^{11}NO^4$.

76]. $Z,C^3H^4,C^6H^4Z;\ C^2H^2O^4$.

Gerhardt's nitrophenyl-pyrotartrimide, or pyrotartronitranile $= C^{10}H^6(C^{12}H^4NO^4)NO^4 = C^{22}H^{10}N^2O^8$.

77]. $ZH,C^6H^5;\ C^3H^4O + H;\ C^2H^2O^2$.

Gerhardt's phenyl-pyrotartramic acid, or pyrotartranilic acid $= C^{10}H^8(C^{12}H^5)NO^6 = C^{22}H^{13}NO^6$.

78]. This is merely the lead-salt of the "acid," No. 77.

79]. $ZH,C^6H^4Z;\ C^3H^4O^3 + H;\ C^2H^2O^2$.

Gerhardt's nitrophenyl-pyrotartramic acid, or pyrotartronitranilic acid $= C^{10}H^8(C^{12}H^4NO^4)NO^6 = C^{22}H^{12}N^2O^{10}$.

What do Gerhardt's formulæ teach us in regard to the proximate constitution of these amidogen salts? Absolutely nothing. On the other hand, the analysis of these salts on the principles which lead to the formulæ Nos. 74 to 79 afford strong proof of two facts; 1st, that these salts contain amidogens; 2ndly, that pyrotartaric acid contains two acid radicals, one of which forms part of the amidogen contained in each salt. It is important to notice the effects that would be produced by the conversion of these amidogen salts into normal ammonium salts:—

74]. $ZH^3,C^3H^4;\ C^2H^2O^3$.
75]. $ZH^2,C^3H^4,C^6H^5;\ C^2H^2O^3$.
76]. $ZH^2,C^3H^4,C^6H^4Z;\ C^2H^2O^3$.

$$77].\ \left.\begin{array}{rl} ZH^3,C^6H^5 & ;\ C^3H^4O^2 \\ H & ;\ C^2H^2O^2 \end{array}\right\}$$

$$78].\ \left.\begin{array}{rl} ZH^3,C^6H^4Z & ;\ C^3H^4O^4 \\ H & ;\ C^2H^2O^2 \end{array}\right\}$$

The compounds marked 74, 75, and 76, are all succinates. But normal succinates possess only O^2. In 74 and 75 we find O^1 extra, because of the presence of the acid radical adipyl in the condition of a basic radical. In 75 to 78 we have phenyl in the basic radical, but phenyl does not carry O^1 extra into its salts, like acid radicals proper. In 76, we have O^5, namely O^2 for the normal succinate, O^1 for the adipyl, and O^2 for the nitrogen substituted for hydrogen. In 77 we have an acid pyrotartrate precisely similar to No. 63, and containing the normal quantity of oxygen. In the parallel salt, 78, we have O^2 extra on account of the substituted nitrogen. Thus we can account for every atom, and we find that each has its duty to do, and does it.

THE PIMELATES. GROUP F. Nos. 80 and 81.

The Pimelates are composed of suberates and adipates, combined atom to atom. No. 80 shows the composition of hydrated pimelic acid, and No. 81, that of its neutral salts.

THE ANCHOATES. GROUP G. Nos. 82 to 85.

The Anchoates have been recently discovered by Mr. G. B. Buckton (*Quarterly Journal Chemical Society*, x. 166) among the products obtained by treating Chinese wax with nitric acid.

According to Professor Brodie, Chinese wax contains two of the superior members of the vinyl series of radicals; its composition being

$$C^{27}H^{55},C^{27}H^{53}O^{2} = \text{Ceryla cerotylete.}$$

When this salt is heated with strong nitric acid, it splits up into a variety of salts, which contain radicals both of the vinyl series and of the succinic series. Since the radicals of the vinyl series are convertible into radicals of the succinic series by oxidation and loss of hydrogen, while the radicals of the succinic series are convertible into those of the vinyl series by loss of carbonic acid,—see page 442,—it is of course to be expected that, when any salt which contains a complex member of the vinyl series is heated with nitric acid, various members of both series of radicals, all less complex in structure than the radical that is operated upon, will appear amongst the products of the decomposition.

Accordingly, Mr. Buckton found all the following compounds in the liquor produced by the operation above described:—

Belonging to the Succinic Group.	*Belonging to the Vinyl Group.*
Anchoic acid.	Œnanthylic acid.
Suberic acid.	Butyric acid.
Pimelic acid.	Caprylic acid.

The formulæ given by Mr. Buckton to the anchoates are as follow:—

$C^{18}H^{16}O^{8}$ = Anchoic acid.
$C^{18}(H^{14}Ag^{2})O^{8}$ = Anchoate of silver.

He considers the anchoic acid to be a new and peculiar bibasic acid; but the only evidence produced in support of the bibasic character is the acid potash salt, No, 85; which, to my mind, is no evidence at all, since this compound may be explained as a double salt composed of neutral sebate of potash and hydrated suberic acid. When the amidogen salts of this "acid" come to be examined, they will no doubt be found to be analogous in constitution to those of the pyrotartaric acid.

In conclusion, I assume it to be proved, that all the salts of the succinic group, like those of the malic and citric groups, can be described with precision as MONOBASIC Salts; and that there is no evidence to justify the assumption that they are BIBASIC. In the absence of proof of the existence of bibasic characters, the law of simplicity demands our stedfast adherence to the Monobasic Theory.

The Salicylic Group.

The Salicylates appear to me to be formed on the model of the Carbonates, and they are consequently BIBASIC in the same definite sense that the carbonates are bibasic. Thus:

$MO + MO + C\quad O = M,M;\ C\quad O^{3}$ = Carbonate.
$MO + MO + C^{7}H^{4}O = M,M;\ C^{7}H^{4}O^{3}$ = Salicylate.

There is no known salt which bears to the salicylates the relation that the oxalates bear to the carbonates, namely, a salt of the formula $MO + C^{7}H^{4}O = M,C^{7}H^{4}O^{2}$. The salts that are now called salicylites have the formula $M,C^{7}H^{5}O^{2}$, which resembles that of the benzoates. They are monobasic, and the radical $C^{7}H^{5}$ does not belong to the salicylic group. I propose to call that radical spiryl. Then, salicylous acid, or the hydride of salicyl, the essential oil prepared from the flowers of the meadow-sweet (*Spiræa ulmaria*), will be $H,C^{7}H^{5}O^{2}$ = Hydra spirylete.

It is possible that salicyl = $C^{7}H^{4}$, may be hereafter discovered to be a double radical; but I have at present no evidence of such a discovery, and therefore I admit it to be a single radical, having the power to produce salts with two basic radicals, in the manner of the carbonates.

Examples of Salts that contain Salicyl.

A. NORMAL SALICYLATES.

1.	$H \; ; H \; ; C^7H^4O^3$	Hydra hydra salicylite.
2.	$\left\{ \begin{array}{l} H \; ; H \; ; C^7H^4O^3 \\ \qquad\qquad C^7H^4O^2 \end{array} \right\}$	Hydra hydra salicylite cum salicylete.
3.	$C^7H^4O^2$	Salicylete.
4.	$Ba \; ; Ba \; ; C^7H^4O^3$	Baryta baryta salicylite.
5.	$Pb \; ; Pb \; ; C^7H^4O^3$	Plumba plumba salicylite.
6.	$Cuc \; ; Cuc \; ; C^7H^4O^3$	Cupric cupric salicylite.
7.	$H \; ; Ba \; ; C^7H^4O^3$	Hydra baryta salicylite.
8.	$H \; ; Pb \; ; C^7H^4O^3$	Hydra plumba salicylite.
9.	$H \; ; Cuc \; ; C^7H^4O^3$	Hydra cupric salicylite.
10.	$H \; ; ZH^4 \; ; C^7H^4O^3$	Hydra ammona salicylite.
11.	$H \; ; ZH^2 \; ; C^7H^4O^3$	Hydra amida salicylite.
12.	$K \; ; Cuc \; ; C^7H^4O^3$	Potassa cupric salicylite.
13.	$Ba \; ; Cuc \; ; C^7H^4O^3$	Baryta cupric salicylite.
14.	$H \; ; C\,H^3 ; C^7H^4O^3$	Hydra methyla salicylite.
15.	$Ba \; ; C\,H^3 ; C^7H^4O^3$	Baryta methyla salicylite.
16.	$Ag \; ; C\,H^3 ; C^7H^4O^3$	Argenta methyla salicylite.
17.	$K \; ; C\,H^3 ; C^7H^4O^3$	Potassa methyla salicylite.
18.	$CH^3 \; ; C\,H^3 ; C^7H^4O^3$	Methyla methyla salicylite.
19.	$C^2H^5 \; ; C\,H^3 ; C^7H^4O^3$	Ethyla methyla salicylite.
20.	$C^5H^{11} ; C\,H^3 ; C^7H^4O^3$	Amyla methyla salicylite.
21.	$H \; ; C^2H^5 ; C^7H^4O^3$	Hydra ethyla salicylite.
22.	$C^2H^5 \; ; C^2H^5 ; C^7H^4O^3$	Ethyla ethyla salicylite.
23.	$H \; ; C^5H^{11} ; C^7H^4O^3$	Hydra amyla salicylite.

B. SALICYLATES IN WHICH ACID RADICALS ACT AS BASIC.

24.	$H \; ; C^2\,H^3 \; ; C^7H^4O^4$	Hydra acetyla salicylote.
25.	$C\,H^3 \; ; C^{10}H^{11} ; C^7H^4O^4$	Methyla cumyla salicylote.
26.	$C\,H^3 \; ; C^2\,H^2 \; ; C^7H^4O^4$	Methyla succinyla salicylote.
27.	$H \; ; C^7\,H^5 \; ; C^7H^4O^4$	Hydra benzyla salicylote.
28.	$C\,H^3 \; ; C^7\,H^5 \; ; C^7H^4O^4$	Methyla benzyla salicylote.
29.	$C^2H^5 \; ; C^7\,H^3 \; ; C^7H^4O^4$	Ethyla benzyla salicylote.
30.	$C^5H^{11} ; C^7\,H^5 \; ; C^7H^4O^4$	Amyla benzyla salicylote.
31.	$H ; ZH,C^7H^5 \; ; C^7H^4O^3$	Hydra benzylac salicylite.

C. HIPPURATES.

32.	$H \; ; ZH,C^2H^3 ; C^7H^4O^3$	Hydra glycolac salicylite.
33.	$Ag \; ; ZH,C^2H^3 ; C^7H^4O^3$	Argenta glycolac salicylite.
34.	$ZH^4 \; ; ZH,C^2H^3 ; C^7H^4O^3$	Ammona glycolac salicylite.

35.	$\left\{\begin{matrix} ZH^4 ; ZH,C^2H^3 ; C^7H^4O^3 \\ H ; ZH,C^2H^3 ; C^7H^4O^3 \end{matrix}\right\}$	Ammona glycolac salicylite cum hydra glycolac salicylite.
36.	$C^2H^5 ; ZH,C^2H^3 ; C^7H^4O^3$	Ethyla glycolac salicylite.
37.	$H ; ZH,C^2H^3 ; C^7H^3ZO^5$	Hydra glycolac zotic-salicylute.
38.	$Ag ; ZH,C^2H^3 ; C^7H^3ZO^5$	Argenta glycolac zotic-salicylute.

D. BENZO-GLYCOLLATES.

39.	$H ; C^2H^3 ; C^7H^4O^4$	Hydra glycola salicylote.
40.	$Ag ; C^2H^3 ; C^7H^4O^4$	Argenta glycola salicylote.
41.	$Ba ; C^2H^3 ; C^7H^4O^4$	Baryta glycola salicylote.

E. BENZO-LACTATES.

42.	$H ; C^3H^5 ; C^7H^4O^4$	Hydra lactyla salicylote.
43.	$Ag ; C^3H^5 ; C^7H^4O^4$	Hydra lactyla salicylote.

F. MANDELATES, OR FORMO-BENZOYLATES.

44.	$H ; CH^3 ; C^7H^4O^3$	Hydra methyla salicylite.
45.	$Ba ; CH^3 ; C^7H^4O^3$	Baryta methyla salicylite.
46.	$Ag ; CH^3 ; C^7H^4O^3$	Argenta methyla salicylite.

G. SALICYLATES, CONTAINING BROMIC AND CHLORIC-SALICYL.

47.	$H ; H ; C^7H^3Cl\,O^3$	Hydren chloric-salicylite.
48.	$H ; H ; C^7H^3Br\,O^3$	Hydren bromic-salicylite.
49.	$H ; H ; C^7H^2Br^2O^3$	Hydren bromenic-salicylite.
50.	$H ; H ; C^7H\,Br^3O^3$	Hydren brominic-salicylite.
51.	$H ; C\,H^3 ; C^7H^3Cl\,O^3$	Hydra methyla chloric-salicylite.
52.	$H ; C^2H^5 ; C^7H^2Br^2O^3$	Hydra ethyla bromenic-salicylite.

H. SALICYLATES, CONTAINING AZOTIC-SALICYL.

53.	$H ; H ; C^7H^3Z\,O^5$	Hydren zotic-salicylute.
54.	$H ; H ; C^7H^2Z^2O^7$	Hydren zotenic-salicyleze.
55.	$H ; H ; C^7H\,Z^3O^9$	Hydren zotinic-salicyloze.
56.	$H ; Z\,H^4 ; C^7H^3Z\,O^5$	Hydra ammona zotic-salicylute.
57.	$H ; Z\,H^2 ; C^7H^3Z\,O^4$	Hydra amida zotic-salicylote.
58.	$H ; Pb ; C^7H^3Z\,O^5$	Hydra plumba zotic-salicylute.
59.	$Pb ; Pb ; C^7H^3Z\,O^5$	Plumba plumba zotic-salicylute.
60.	$\left\{\begin{matrix} H ; Pb ; C^7H^3Z\,O^5 \\ Pb ; Pb ; C^7H^3Z\,O^5 \end{matrix}\right\}$	Hydra plumbine bis zotic-salicylute.
61.	$H ; C^2H^5 ; C^7H^3Z\,O^5$	Hydra ethyla zotic-salicylute.
62.	$H ; Ba ; C^7H^2Z^2O^7$	Hydra baryta zotenic-salicyleze.
63.	$Ba ; Ba ; C^7H^2Z^2O^7$	Baryta baryta zotenic-salicyleze.

64. $H\ ;\ CH^3 ;\ C^7H^2Z^2O^7$ . . Hydra methyla zotenic-salicyleze.

65. $ZH^4 ;\ CH^3 ;\ C^7H^2Z^2O^7$ . . Ammona methyla zotenic-salicyleze.

66. $H\ ;\ CH^3 ;\ C^7H\ Z^3O^9$ . . Hydra methyla zotinic-salicyloze.

Investigation of the Salts of Salicyl.

GROUP A. NORMAL SALICYLATES.

$$1].\ H ; H ; C^7H^4O^3. \quad 2].\left\{\begin{matrix} H ; H ; C^7H^4O^3 \\ C^7H^4O^2 \end{matrix}\right\}. \quad 3].\ C^7H^4O^2.$$

No. 1 is the hydrated salicylic acid, No. 2 the anhydrous salicylic acid, and No. 3 is salicylid. The two latter are produced by acting on salicylate of soda by oxychloride of phosphorus. Thus:

$$\left.\begin{matrix} H ; Na ; C^7H^4O^3 \\ H ; Na ; C^7H^4O^3 \\ H ; Na ; C^7H^4O^3 \\ + \quad Cl^3PO \end{matrix}\right\} = \left\{\begin{matrix} NaPO^3 & \\ NaCl + NaCl + HCl & \\ H ; H ; C^7H^4O^3 + C^7H^4O^2 & = \text{No. } 2. \\ C^7H^4O^2 & = \text{No. } 3. \end{matrix}\right.$$

The term "anhydrous" acid was given to No. 2 by Gerhardt, on the presumption that the radical salicyl was C^7H^5, a constitution which is incompatible with the fact that the salicylates are bibasic. No. 3 is the true anhydrous salicylic acid, just as CO^2 is the anhydrous carbonic acid.

Nos. 4] to 23], with the exception of No. 11], present examples of normal salicylates, neutral and acid, the whole of which are so regular that they scarcely demand explanation. A very few words will suffice. No. 11 is the salicylamid derived from the ammonium salt No. 10. No 14 is the oil of winter-green, gaultheric acid, hydrate of methylsalicyle, salicylate of methyl, methyl-salicylic acid, or methyl-spiroylic acid, for it has all these names, and more. Nos. 15 to 20 are salts of the methylsalicylic acid. No. 21 is ethylsalicylic acid, and No. 23 is amylsalicylic acid. There is, of course, not the least necessity to treat these salts as conjugated acids. An inspection of the Table shows that they are all regular bibasic salicylates, and that the salts from No. 4 to 13 have the same right to be elevated to the rank of conjugated acids as the salts from Nos. 14 to 23.

GROUP B. SALICYLATES WHICH CONTAIN ACID RADICALS IN THEIR BASES.

The salts from No. 24 to 30, all contain an acid radical acting as one of their basic radicals, and consequently every one of them possesses an additional atom of oxygen, in accordance with the observation which I have recorded at page 376. In other respects, these salts resemble normal salicylates. In No. 31, the amidogen salt is deficient of O^1, because it is an amidogen salt. If it were completed to an ammonium salt, the O^3 would have O^4 like the other salts in Group B. Gerhardt's names for this group of salts are as follows: 24, Anhydrous acetosalicylic acid, acetate of salicyl, or salicylate of acetyl. 25, Cuminate of methylo-salicyl, or oxide of cumyl and methylo-salicyl; formula

$$\left.\begin{matrix} C^7H^4(CH^3)O^2 \\ C^{10}H^{11}O \end{matrix}\right\} O.$$

26, Succinate of methylo-salicyl, or oxide of succinyl and methylo-salicyl

$$= \begin{matrix} \left.\begin{matrix} C^7H^4(CH^3)O^2 \\ C^7H^4(CH^3)O^2 \end{matrix}\right) O. \\ C^4H^4O^2,O \end{matrix}$$

In this formula everything is doubled, in order to make succinyl appear to be a bibasic radical.

27, Anhydrous benzosalicylic acid, benzoate of salicyl, or salicylate of benzoile. 28, Benzoate of methylo-salicyl, or oxide of benzoyl and methylo-salicyl. 29, Benzoate of ethylo-salicyl, or oxide of benzoyl and ethylo-salicyl. 30, Benzoate of amylo-salicyl. 31, Benzoylsalicylamid.

Gerhardt's formulæ show that he considered the salicyl radical to be C^7H^5, and that he assumed that it had the power of exchanging H^1 for a complete hydrocarbon. It appears to me, that that assumption is erroneous and hazardous. The hydrogen in amidogens and ammoniums can be exchanged for complete radicals, but I do not believe that, in any case, the hydrogen of a hydrocarbon can be replaced by another complete hydrocarbon. If such substitutions could occur, the individuality of all compound radicals, and consequently the power to identify them, would speedily be lost. In Gerhardt's formulæ for No. 26, we perceive that he places oxygen in five different situations, a pretty wide scattering of one element in one salt, to be advocated by the great champion of *unitary* formulæ.

THE CONJUGATED BENZOATES. GROUPS C to F.

The salts constituting Groups C to F, Nos. 32 to 46, are usually represented as salts of conjugated acids, containing benzyl as one of their negative elements. I refer them in preference to the salicylic group, for the following reasons:—

1. They are not conjugated salts, but merely bibasic salts, and their quantum of hydrogen agrees with that of salicyl and not with that of benzyl.

2. The quantity of oxygen contained in each salt agrees with that

which is necessary to constitute a salicylate, and not with that which is required to complete a benzoate.

3. In so far as regards the properties of the salts, and the products of their decomposition, they may be as properly referred to the salicylic as to the benzoic group.

A glance over the relationship of the radicals which are depicted in the Tables, will satisfy the reader that these reasons are forcible.

Usual Names of the Salts.

C. HIPPURATES. 32, Hippuric acid. 33, Hippurate of silver. 34, Hippurate of ammonia. 35, Acid hippurate of ammonia. 36, Hippuric ether. 37, Nitrohippuric acid. 38, the silver salt of the acid No. 37.

I refrain from quoting the common formulæ, because I have so frequently discussed the merits and demerits of all kinds of formulæ, that farther repetitions are needless, unless peculiar points require elucidation.

D. BENZOGLYCOLLATES. 39, the benzoglycollic acids. 40, its silver salt. 41, its barium salt.

E. BENZOLACTATES. 42, the benzolactic acid. 43, its silver salt.

F. MANDELATES. 44, the mandelic acid. 45, its barium salt. 46, its silver salt. The mandelates, 44, 45, 46, are isomeric with the gaultheriates, 14, 15, 16—just as the hydride of salicyl is isomeric with benzoic acid, both = $H,C^7H^5O^2$. I do not know whether they are identic as well as isomeric.

I might fill a long chapter with an inquiry into the merits of the different theories that have been suggested to explain the constitution of these four classes of salts. But if the reader will kindly look into the systematic works of Gerhardt, Gmelin, &c., and compare the various hypotheses he finds there with that which is now presented to him, he will have no difficulty in determining on which side there is simplicity and probability of truth.

Group G. CONJUGATED SALICYLATES, CONTAINING BROMIC AND CHLORIC-SALICYL.

There is nothing in these salts that requires particular explanation. The quantity of oxygen is the same as that which is required to complete normal salicylates, because the bromic and chloric vice-radicals take the same quantity of oxygen to form salts as do the corresponding normal radicals.

Group H. CONJUGATED SALICYLATES, CONTAINING AZOTIC-SALICYL.

These salts differ from normal salicylates only by containing zotic-salicyl instead of normal salicyl, and an increase in the quantity of oxygen in each salt, at the rate of O^2 for every Z^1 which goes into the acid radical.

The Tartrates.

The atomic weights represented by the symbols given in the following Table are stated at page 28.

GROUP A. TARTARIC ACID.

1. $\mathrm{H,C^2H^2O^3}$

2. $\mathrm{C^2H^2, \quad C^2H^2O^5}$

3. $\left\{\begin{array}{l}\mathrm{H,C^2H^2O^3 + H,C^2H^2O^3} \\ \mathrm{C^2H^2, \quad C^2H^2O^5}\end{array}\right.$

GROUP B. NORMAL, NEUTRAL, OR MONOBASIC TARTRATES.

4. $\mathrm{K\ ,C^2H^2O^3}$
5. $\mathrm{Na\ ,C^2H^2O^3}$
6. $\mathrm{ZH^4,C^2H^2O^3}$
7. $\mathrm{Ca\ ,C^2H^2O^3}$
8. $\mathrm{Ag\ ,C^2H^2O^3}$
9. $\mathrm{Pb\ ,C^2H^2O^3}$
10. $\mathrm{Cuc,C^2H^2O^3}$
11. $\mathrm{Sn\ ,C^2H^2O^3}$
12. $\mathrm{Fec\ ,C^2H^2O^3}$
13. $\mathrm{ZHHgc^3,C^2H^2O^3}$
14. $\mathrm{C\,H^3\ ,C^2H^2O^3}$
15. $\mathrm{C^2H^5\ ,C^2H^2O^3}$

GROUP C. TERBASIC TARTRATES.

16. $\mathrm{Sbc^3,C^2H^2O^4}$
17. $\mathrm{Uc^3\ ,C^2H^2O^4}$
18. $\mathrm{H^2Bic,C^2H^2O^4}$
19. $\mathrm{H^2Na,C^2H^2O^4}$

GROUP D. ACID TARTRATES.

20. $\mathrm{K,C^2H^2O^3 + H,C^2H^2O^3}$
21. $\mathrm{ZH^4,C^2H^2O^3 + H,C^2H^2O^3}$

GROUP E. AMIDOGEN SALTS.

22. $\mathrm{ZH^2,C^2H^2O^2}$ . . . . Amida tartrylete.

23. $\left\{\begin{array}{l}\mathrm{ZH^2,C^2H^2O^2 + H,C^2H^2O^3} \\ \mathrm{= H\,;\ ZH^2\,;\ (C^2H^2)^2O^5}\end{array}\right\}$ Hydra amida tartrylenute.

24. $\left\{\begin{array}{l}\mathrm{ZH^2,C^2H^2O^2 + C^2H^5,C^2H^2O^3} \\ \mathrm{= C^2H^5\,;\ ZH^2\,;\ (C^2H^2)^2O^5}\end{array}\right\}$ Ethyla amida tartrylenute.

GROUP F. DOUBLE TARTRATES.

25. $\mathrm{K,C^2H^2O^3 + Na\ ,C^2H^2O^3}$
26. $\mathrm{K,C^2H^2O^3 + ZH^4,C^2H^2O^3}$
27. $\mathrm{K,C^2H^2O^3 + Cuc,C^2H^2O^3}$
28. $\mathrm{Na,C^2H^2O^3 + Ba\ ,C^2H^2O^3}$
29. $\mathrm{Na,C^2H^2O^3 + ZH^4,C^2H^2O^3}$
30. $\mathrm{Na,C^2H^2O^3 + Mg\ ,C^2H^2O^3}$

GROUP G. CONJUGATED TARTRATES.

31. $\mathrm{C\,H^3,C^2H^2O^3 + H,C^2H^2O^3}$
32. $\mathrm{C\,H^3,C^2H^2O^3 + K,C^2H^2O^3}$
33. $\mathrm{C^2H^5,C^2H^2O^3 + H,C^2H^2O^3}$
34. $\mathrm{C^2H^5,C^2H^2O^3 + K,C^2H^2O^3}$
35. $\mathrm{C^2H^5\ ,C^2H^2O^3 + Ba\ ,C^2H^2O^3}$
36. $\mathrm{C^2H^5\ ,C^2H^2O^3 + Ag,C^2H^2O^3}$
37. $\mathrm{C^5H^{11},C^2H^2O^3 + H\ ,C^2H^2O^3}$
38. $\mathrm{C^5H^{11},C^2H^2O^3 + Ag,C^2H^2O^3}$

GROUP H. TETRABASIC TARTRATES.

39. $\mathrm{Na\ ,C^2H^2O^3 + H^3\ ,C^2H^2O^4}$
40. $\mathrm{H\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
41. $\mathrm{Na\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
42. $\mathrm{ZH^4,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
43. $\mathrm{K\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
44. $\mathrm{Ba\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
45. $\mathrm{Ag\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
46. $\mathrm{Pb\ ,C^2H^2O^3 + Sbc^3,C^2H^2O^4}$
47. $\mathrm{ZH^4,C^2H^2O^3 + Asc^3,C^2H^2O^4}$
48. $\mathrm{K\ ,C^2H^2O^3 + Fec^3,C^2H^2O^4}$
49. $\mathrm{ZH^4,C^2H^2O^3 + Fec^3,C^2H^2O^4}$
50. $\mathrm{H\ ,C^2H^2O^3 + HFec^2,C^2H^2O^4}$
51. $\mathrm{H\ ,C^2H^2O^3 + Crc^3,C^2H^2O^4}$
52. $\mathrm{K\ ,C^2H^2O^3 + Crc^3,C^2H^2O^4}$
53. $\mathrm{Na\ ,C^2H^2O^3 + Cuc^3,C^2H^2O^4}$
54. $\mathrm{K\ ,C^2H^2O^3 + B^3,C^2H^2O^4}$
55. $\mathrm{H\ ,C^2H^2O^3 + U^3,C^2H^2O^4}$
56. $\mathrm{K\ ,C^2H^2O^3 + U^3,C^2H^2O^4}$

GROUP I. DOUBLE TARTRATES, CONTAINING VICE-TARTRYLS.

57. $\mathrm{H\ ,C^2HSbcO^3 + Sbc\ ,C^2HSbcO^3}$
58. $\mathrm{K\ ,C^2HSbcO^3 + Sbc\ ,C^2HSbcO^3}$
59. $\mathrm{Ba\ ,C^2HSbcO^3 + Sbc\ ,C^2HSbcO^3}$
60. $\mathrm{Ag,C^2HSbcO^3 + Sbc\ ,C^2HSbcO^3}$
61. $\mathrm{Pb,C^2HSbcO^3 + Sbc\ ,C^2HSbcO^3}$
62. $\mathrm{K\ ,C^2HBic\,O^3 + Bic\ ,C^2HBic\,O^3}$
63. $\mathrm{K\ ,C^2HB\ \ O^3 + B\ \ ,C^2HB\ \ O^3}$

GROUP K. COMPLEX TARTRATES.

$$64.\ \left\{\begin{array}{rlrl} \mathrm{H^3,C^2H^2} & \mathrm{O^4 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{H^3,C^2H^2} & \mathrm{O^4 +} & \mathrm{H^3,C^2H^2} & \mathrm{O^4} \end{array}\right\}$$

$$65.\ \left\{\begin{array}{rlrl} \mathrm{Sbc\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{Sbc\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc\ ,C^2H^2} & \mathrm{O^3} \end{array}\right\}$$

$$66.\ \left\{\begin{array}{l} \left.\begin{array}{rlrl} \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{H\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{H\ ,C^2H^2} & \mathrm{O^3} \end{array}\right\} \\ \text{or else—} \\ \left.\begin{array}{rlrl} \mathrm{H\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{H\ ,C^2H^2} & \mathrm{O^3} \end{array}\right\} \end{array}\right.$$

$$67.\ \left\{\begin{array}{rlrl} \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{H\ ,C^2H^2} & \mathrm{O^3} \\ \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{H\ ,C^2H^2} & \mathrm{O^3} \\ \mathrm{K\ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{H\ ,C^2H^2} & \mathrm{O^3} \end{array}\right\}$$

$$68.\ \left\{\begin{array}{rlrl} \mathrm{KH^2,C^2H^2} & \mathrm{O^4 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \\ \mathrm{K\ \ ,C^2H^2} & \mathrm{O^3 +} & \mathrm{Sbc^3,C^2H^2} & \mathrm{O^4} \end{array}\right\}$$

69. $\mathrm{Sbc\ ,C^2H\ SbcO^3 + Sbc^3,C^2H\ SbcO^4}$
70. $\mathrm{Sbc^3,C^2H^2\ \ O^4 + Uc^3,C^2H^2\ \ O^4}$
71. $\mathrm{Sbc\ ,C^2H\ SbcO^3 + Uc^3,C^2H\ SbcO^4}$
72. $\mathrm{BaH^2,C^2H^2\ \ O^4 + Sbc^3,C^2H^2\ \ O^4}$
73. $\mathrm{Sbc^3H^2,C^2H^2\ \ O^5 + Sbc^3,C^2H^2\ \ O^4}$

GROUP L. ANILIDES OF TARTARIC ACID.

	Formula		Name
74.	$ZH, C^6H^5; C^2H^2O^2$	. .	Phenylac tartrylete.
75.	$\left\{\begin{array}{r} ZH, C^6H^5; C^2H^2O^2 \\ H; C^2H^2O^3 \end{array}\right\}$	. .	Phenylac tartrylete cum hydra tartrylite.
76.	$\left\{\begin{array}{r} ZH, C^6H^5; C^2H^2O^2 \\ Ba; C^2H^2O^3 \end{array}\right\}$	. .	Phenylac tartrylete cum baryta tartrylite.
77.	$\left\{\begin{array}{r} ZH, C^6H^5; C^2H^2O^2 \\ Ag; C^2H^2O^3 \end{array}\right\}$	. .	Phenylac tartrylete cum argenta tartrylite.
78.	$Z, C^2H^2, C^6H^5; C^2H^2O^4$	. .	Tartrylic-phenylac tartrylote.

The constitution of TARTRYL, the radical of Tartaric Acid, is C^2H^2. Its salts are *monobasic*, but they combine with one another in endless variety. The classification in the Table is intended to show the principal forms of the compound salts which are thus produced.

A peculiarity of tartaric acid is, that it not only gives origin to salts which resemble the salts of monobasic acids, usually so-called, such as the acetates; but also to the acid salts and double salts which characterise the acids that are commonly called bibasic, such as the sulphates and oxalates; and, finally, to a third series, which includes the three different forms of salts that so remarkably distinguish the phosphates.

Thus, in Group B, we have a series of monobasic salts; in Group D, acid double salts; in Group F, neutral double salts; in Group C, we perceive terbasic salts, formed like the terbasic phosphates; and in Group H, we find combinations of monobasic salts with terbasic salts, affording compounds that are precisely similar in constitution to the bibasic pyrophosphates.

The variety which exists among the tartrates is still further increased by the circumstance that, under the action of heat, the radical tartryl can exchange one atom (the half) of its hydrogen, for a metalloid or an acidifiable metal, and thus produce a vice-radical, which retains the power of forming salts. Among the vice-tartryls thus produced, I may cite stibic-tartryl, arsanic-tartryl, ferric-tartryl, chromic-tartryl, bismic-tartryl, uranic-tartryl, and boric-tartryl. Examples of the salts of these vice-radicals are quoted in Groups I and K.

A knowledge of these particulars enables us to comprehend the constitution of the tartrates, which would otherwise appear to be not a little perplexing. I shall briefly run over the list of examples, and quote the common names of the leading salts. A particular account of the whole of them may be seen in the *Traité de Chimie* of Gerhardt, and the *Handbook of Chemistry* of Gmelin.

GROUP A. *Tartaric Acid.*—1]. Crystallised tartaric acid. The formula given by Gerhardt is $C^8H^6O^{12}$. Gmelin's formulæ are $C^8H^6O^{12}$ and $C^8H^6O^6,O^6$. These formulæ represent the acid as bibasic, and they assume the atomic weight of C to be 6, and that of O to be 8. As these formulæ of the acid are so much more complicated than that which is given in No. 1, it may be inferred that the formulæ that are given by the same chemists to the various tartrates, are also more complicated and cumbersome than those that are given in the above Table. That is actually the case; but I shall forbear the quotation of them, because they present no particularly novel points, and I have already sufficiently discussed the ordinary characters of organic formulæ. 2]. The tartaric acid anhydride. 3]. A combination of the anhydride with two atoms of the hydrated acid. This compound is usually called *tartrelic acid.* A similar compound, containing one atom of the anhydride with six atoms of the hydrated acid, has been called *tartralic acid.* I mention these particulars to show that various combinations are formed by hydrated and anhydrous tartaric acid, and that chemists are in the habit of describing such compounds as *new acids.* It may be doubted whether that practice is judicious. If you apply heat to a number of atoms of hydrated tartaric acid, *or of any tartrate,* you can, according to the degree of heat applied, and to the duration of its application, drive off more or less HHO, and consequently more or less change the constitution of the substance so exposed to heat. When the crystallised acid is so treated, the product may be a mere mixture of

$$x\mathrm{H,C^2H^2O^3} + x\mathrm{C^2H^2,C^2H^2O^5}$$

and is not necessarily a *new acid.* When a salt is so treated, it passes from one class to another class of the salts described in the foregoing Table, and *seems* to become a new salt, yet—when the dried salt is exposed to the action of water, it recovers ts original condition.

Group B. *Normal, Neutral, or Monobasic Tartrates,*

4] of potash.
5] of soda.
6] of ammonia.
7] of lime.
8] of silver.
9] of lead.
10] of copper.
11] of tin.
12] of iron.
13] of mercury-ammonium.
14] of methyl.
15] of ethyl.

The characteristics of the salts of this group are, that one basic radical is combined in them with one atom of normal tartryl and with $\mathrm{O^3}$. These monobasic salts can be converted into apparently-bibasic salts, by the easy process, described at page 395, of doubling the formulæ. Thus, $\mathrm{K,C^2H^2O^3} \times 2$ becomes $\mathrm{KK,C^4H^4O^6}$, to which formula it would be judicious to add in all cases *cui bono?*

Group C. *Terbasic Tartrates.* These salts agree in composition with the terbasic phosphates—see page 138; thus, No. 16 is $\mathrm{Sbc,C^2H^2O^3}$ + Sbc,SbcO, namely, it is a monobasic tartrate of Group B, combined with a salt formed on the model of water. 16]. Neutral tartrate of antimony. 17]. Tartrate of sesquioxide of uranium. 18]. Tartrate of bismuth. 19]. Neutral tartrate of soda. The acid tartrate of soda is No. 39. As commonly represented in chemical books, the salts 16 and 17 contain ($\frac{1}{2}$ aq) in addition to the constituents represented in these formulæ. Thus No. 16 is represented as $2SbO^3,C^8H^6O^{12}$, and No. 17 as $2U^2O^3,C^8H^6O^{12}$, which formulæ are expressed by No. 73. This difference may be due to the presence of a little extra water, or it may arise from error in analysis. The tartrates lose water gradually while in course of drying, and there is no fixed temperature at which standards can be taken, while they suffer from the disadvantage that, being frequently decomposable by pure water, they cannot be washed clean previous to analysis. However, the presence of additional water in these salts does not invalidate the terbasic formulæ, any more than the presence of water of crystallisation invalidates the formulæ of the terbasic phosphates. No. 19 represents a neutral crystallised salt which has been frequently analysed, and the composition of which appears to be free from doubt.

These salts are of course all changed in composition when heated. No. 16 represents a salt dried at 100° C. If heated to 190° C, it is changed into No. 69. This is explained by the following equation:

$$\left.\begin{array}{l} Sbc^3,C^2H^2O^4 \\ Sbc^3,C^2H^2O^4 \end{array}\right\} = \left\{\begin{array}{l} Sbc,C^2HSbcO^3 + Sbc^3,C^2HSbcO^4 \\ \qquad\quad H \qquad O \; + \qquad\qquad H \end{array}\right.$$

There being in No. 16 no ready-formed water separable by the increased heat, the tartryl undergoes substitution of Sbc for H, to the extent of half its hydrogen, but never more without entire destruction to the acid. In like manner, No. 17 produces a salt equivalent to No. 69, but having 6 Uc instead of 6 Sbc. The salts Nos. 16 and 17 combine together, to produce the compound No. 70, and when this compound is dried at 200° C, it is reduced to the condition of No. 71. The salt No. 16 combines with three atoms of hydrated acid and three atoms of water to form the quadrotartrate No. 64. It combines with three atoms of monobasic tartrate (not known in the separate state) to form the quadruple salt commonly called acid tartrate of antimony No. 65. It combines with one atom of the monobasic acid No. 1, to form the tetrabasic salt No. 40, and when No. 40 is dried at 160° C, it produces the double vice-tartrylate No. 57. It is evident, from these examples, that if C^2H^2, the acid radical of tartaric acid, was as indestructible by heat as P^2, the acid radical of phosphoric acid, it would be easy to produce among the tartrates, with any given positive radical, every variety of salt which is producible among the phosphates.

When No. 19 is heated, it loses HHO and becomes No. 5. No. 18 probably undergoes a similar reduction to $Bic,C^2H^2O^3$.

GROUP D. *Acid Tartrates.* 20]. This is the fundamental salt of the tartaric series—cream of tartar or bitartrate of potash. 21]. The acid tartrate of ammonia. Soda forms a similar salt, namely, $Na,C^2H^2O^3 + H,C^2H^2O^3$.

GROUP E. *Amidogen Salts.* 22]. Tartramide, derived, as usual, from the normal tartrate of ammonium No. 6, by abstraction of H,HO. 23]. Tartramic acid, derived from the acid tartrate of ammonia No. 21, by abstraction of H,HO. 24]. Tartramate of ethyl, or tartramethane. No. 22, tartramide, is quoted at No. 172, page 211, in the list of amids. No. 23, tartramic acid, belongs to the amidogen acids with compound radicals, which are described in Group C, page 227. The evidence from analogy offered by these compounds is in favour of the theory that tartaric acid is monobasic.

GROUP F. *Double Tartrates.* These salts are of the same rank as the double sulphates, page 150, and the double oxalates, page 179. The arguments which I have employed to prove the monobasic nature of sulphuric and oxalic acids apply equally to tartaric acid, and need no repetition. 25]. Tartrate of potash and soda. Salt of Seignette. Rochelle salt. 26]. Tartrate of potash and ammonia. Tartarus solubilis ammoniacalis. 27]. Tartrate of potash and copper. 28]. Tartrate of soda and barytes. 29]. Tartrate of soda and ammonia. 30]. Tartrate of soda and magnesia.

GROUP G. *Conjugated Tartrates.* The conjugated tartrates contain imaginary acids formed in accordance with the fallacious doctrine which I have examined in the chapter on the Bisulphates of the Alcohol Radicals, page 399. All the conjugated tartrates, as is shown by the formulæ Nos. 31 to 38, consist of double tartrates, each containing one positive radical of the vinyl series, and one positive radical of the inorganic series.

31]. Tartaromethylic acid, or methyltartaric acid. 32]. Tartaromethylate of potash. 33]. Tartarovinic acid. 34]. Tartarovinate of potash. 35]. Tartarovinate of barytes. 36]. Tartarovinate of silver. 37]. Amylotartaric acid, or tartramylic acid. 38]. Tartramylate of silver.

Trusting that the reader will examine the arguments which I have urged in the chapter on the Bisulphates of the Alcohol Radicals, and will apply them to the corresponding bitartrates, it is only necessary for me to make here the remark, that the so-called "conjugated" tartrates afford no evidence in favour of the bibasic nature of tartaric acid, but, on the contrary, tend to prove it to be monobasic.

GROUP H. *Tetrabasic Tartrates.* These salts are tetrabasic and biacid, and agree exactly in constitution with the bibasic phosphates, which are also tetrabasic and biacid, and cannot be divided into salts that are bibasic and monacid, because of the uneven number of their atoms of oxygen. These salts are produced by the combination of salts of Group B with those of Group C, atom to atom. It is the same with the phosphates. A monobasic salt and a terbasic salt make together the intermediate wrongly-called bibasic salt.

All the salts of Group H suffer loss of water when heated, and they are thus changed into salts belonging to other groups. No. 39 *minus* HHO, produces a salt equivalent to No. 20 in Group D.

No. 40 — HHO	becomes No.	57.	No. 45 — HHO	becomes No.	60.
43 — HHO	,,	58.	46 — HHO	,,	61.
44 — HHO	,,	59.	54 — HHO	,,	63.

In this change, the tetrabasic and biacid salts are transformed into double monobasic salts, with a conversion of normal tartryl into vice-tartryl. There is, however, no permanent alteration of the acid radical; for if the salts of Group I are treated with water, the normal radical C^2H^2 is again formed, and the salts resume their original constitution. Many of the salts of Group H take up, when crystallised, or when newly precipitated and undried, more water than I have represented in the formula. In particular, tartar emetic No. 43, and several equivalent salts, take up half an atom more water, and assume the constitution that is exhibited by No. 68. With still more water, they acquire the form of No. 72, and with still more, that of No. 73.

39]. Acid tartrate of soda. 40]. See note to 16. 41]. Tartrate of antimony and soda. 42]. Tartrate of antimony and ammonia. 43]. Neutral tartrate of antimony and potash dried at 100° C. Tartar emetic. Tartarised antimony. When this salt is crystallised, it has the composition shown by No. 68. When it is dried at 200° C, it becomes No. 58. When 58 is dissolved in water, it again becomes equal to 43. 44]. Tartrate of antimony and barytes dried at 100° C. When dried at 250° C, it changes to No. 59. When in crystals its composition is represented by No. 72. 45]. Tartrate of antimony and silver, air-dried. When dried at 160° C, it changes to No. 60. 46]. Tartrate of antimony and lead. When dried at 230° C, it becomes No. 61. 47]. Tartrate of arsenious acid and ammonia. 48]. Tartrate of potash and peroxide of iron dried at 100° C. 49]. Tartrate of ammonia and peroxide of iron. 50]. Tartrate of peroxide of iron, according to Gmelin's formula = $2Fe^2O^3,3C^8H^6O^{12}$. If No. 50 were deprived of Aq^1, it would be reduced to the condition of two atoms of No. 12. 51]. Tartrate of sesquioxide of chromium. 52]. Tartrate of potash and sesquioxide of chromium. 53. Tartrate of soda and cupric oxide. 54]. Tartrate of potash and boron. Borotartrate of potash. Soluble tartar. Dried at 100° C. When it is heated to 280° C, it is changed into No. 63. 55]. Tartrate of uranous oxide dried at 100° C. 56]. Tartrate of potash and uranous oxide.

GROUP I. *Double Tartrates containing Vice-Tartryls.* These salts have been so frequently referred to, that farther detail seems needless. The only salt that has not been specially alluded to, is No. 62, which is commonly called the tartrate of potash and bismuth, dried at 200° C. When the salts of this section are dissolved in water, they must be considered to be again restored to the condition of the salts contained in Group H.

GROUP K. *Complex Tartrates.* This list might be extended to a great length, the habits of tartaric acid being such as tend to the indefinite production of such multiple salts. It is sufficient to give a few examples. Nos. 64, 65, 69, 70, and 71, have been already explained in the article on No. 16, Group C. 64]. Supertartrate of antimony. 65]. Acid tartrate of antimony. 66]. Acid cream of tartar, dried at 100° C. This may be considered as a compound of tartar emetic, No. 43, with two atoms of hydrated tartaric acid, No. 1; or as a compound of tartrate of antimony No. 40, with bitartrate of potash, No. 20. 67]. A compound of one atom of tartar emetic, No. 43, with three atoms of cream of tartar, No. 20. 68]. Crystallised tartar emetic; see No. 43. 69, 70, and 71]. See note to No. 16. 72]. See note to No. 44. It is the crystallised tartrate of antimony and barytes. 73]. The freshly-precipitated neutral tartrate of antimony; see No. 16.

GROUP L. *Anilides of Tartaric Acid.* The compounds formed by tartaric acid with aniline have been described by Arppe (*Quarterly Journal Chemical Society*, viii. 179), from whom I copy the following names and formulæ:—

74]. Tartanilide = $C^{32}H^{16}N^2O^8$ = $2C^{12}H^7N.C^8H^6O^{12} - 4HO$. 75]. Tartanilic acid = $C^{20}H^{11}NO^{10}$. 76]. Tartanilate of barytes = $BaO.C^{20}H^{10}NO^9$. 77]. Tartanilate of silver = $AgO.C^{20}H^{10}NO^9$. 78]. Tartanil = $C^{20}H^9NO^8$ = $C^{12}H^7N.C^8H^6O^{12} - 4HO$.

So long as chemists confine themselves to unitary formulæ, or to the equally-enlightening formula of "so-and-so minus so-and so," they must be puzzled to account for the variations in the quantity of oxygen presented by such salts as the above. But on the radical theory, and assuming the propriety of the amidogen theory which I have advanced, every atom described in these formulæ can be rationally accounted for. In 74, we have O^2, because the normal tartrate of phenylam must have O^3 (viz. ZH^3,C^6H^5; $C^2H^2O^3$). In 75, 76, 77, we have O^5, because there is present one amidogen tartrate with O^2, and one normal tartrate with O^3. In 78, we have O^4, because tartryl, when acting as a basic radical, carries O^2 extra into its salts, and in this salt C^2H^2 replaces H^1. In other respects 78 agrees exactly with 74. These anilides prove that tartryl is C^2H^2, and monobasic.

In the foregoing explanation of the constitution of the Tartrates, I have made use of the radicals which, at page 33, I denominated BASYLIC. They effect a decided simplification in the formulæ, by displacing some commonly-received extravagancies.

For example, No. 50, the Tartrate of the peroxide of iron = $H,C^2H^2O^3 + HFec^2,C^2H^2O^4$, is described by Gmelin as follows:

$$2Fe^2O^3,3C^8H^6O^{12}.$$

The symbol $C^8H^6O^{12}$ contained in the above formula, is Gmelin's formula for hydrated tartaric acid; that of his anhydrous acid being

$C^8H^4O^{10}$. We have consequently in this salt, according to this formula, two atoms of base and three double or bibasic atoms of acid. The reason that there are present these proportions of base and acid is, that there are six atoms of oxygen in the given quantity of base, and there must consequently be six atoms of monobasic acid; for it is a law, observable by those who profess to believe in the existence of acids and bases, that a salt must have an atom of acid for every atom of oxygen that is contained in its base.

Turn now to the consideration of the constitution of the double tartrate of potash and peroxide of iron, No. 48 in the above list = $K,C^2H^2O^3 + Fec^3,C^2H^2O^4$. Gmelin's formula for this salt is $C^8H^4K(Fe^2O^2)O^{12}$, and Professor Miller's formula is $KO,Fe^2O^3,C^8H^4O^{10}$. In these formulæ, the law that enjoins a certain correspondence between the quantities of the acid and the base, is set at defiance. Why so? We have four atoms of oxygen in the bases, and we ought therefore to have two atoms of bibasic acid; but we have only one atom. Why so? How comes it that the usual law is observed in the tartrate of iron, but not in the tartrate of potash and iron? Why, in the latter case, is Nature a rebel against the law of the philosophers? Simply because the law is absurd, and Nature cannot observe it.

Take the formula $KO,Fe^2O^3,C^8H^4O^{10}$, and ask yourselves the question, which of these components of the salt is the acid and which is the base? Is Fe^2O^3 a base? If so, the salt ought to have twice its present quantity of acid. Is Fe^2O^3 an acid? If so, we want a base for it, for KO only suffices to saturate half the quantity of acid which is expressed by the symbols $C^8H^4O^{10}$. In short, whether you treat the sesquioxide of iron as acid or as base, you are equally unable to give a rational account of the composition of this salt. So it always is, when you trust to the theory of the sesquioxides to explain a critical case. Your guide betrays you, and down you sink into inextricable muddle. That is surely sufficient reason to induce you to doubt the trustworthiness of your guide, and to look for assistance upon which you can depend. Examine, then, the value of the help offered by the basylic radicals. See how the radical theory applies to these two tartrates.

Gmelin's first formula = $2Fe^2O^3,3C^8H^6O^{12}$, corrected for water becomes $2Fe^2O^3,3C^8H^4O^{10}$. Correcting the atomic weights of the carbon and oxygen, this becomes $Fe^4O^3,C^{12}H^{12}O^{15}$. Exchanging the four ferrous atoms for six ferric atoms, and putting the oxygen together, the product is $Fec^6,C^{12}H^{12}O^{18}$. Dividing this formula by 6, we have $Fec,C^2H^2O^3$, which corresponds with No. 12, and in fact shows that the salt expressed by Gmelin's immense formula, which comprehends 88 ultimate atoms, can, on the radical theory, be clearly expressed by a formula that contains only 8 ultimate atoms, or the eleventh part of Gmelin's quantities. Including the water of Gmelin's formula, the reduced formula becomes No. 50, which contains 19 ultimate atoms.

The formulæ for the double salt is $KO,Fe^2O^3,C^8H^4O^{10}$. Correcting the atomic weights of the iron, the carbon, and the oxygen, and collecting the oxygen together, this formula becomes $K,Fec^3,C^4H^4O^7$, and this thrown into the analytical form becomes

$$K,C^2H^2O^3 + (Fec,C^2H^2O^3 + Fec,Fec\,O),$$

which is equal to No. 48, a formula that exhibits no difficulties, and excites no doubts respecting the functions performed by the atoms of iron.

How simple this explanation appears! How the radical theory scatters the mists that are produced by the hypotheses of "acids" and "bases," and "sesquioxides"—scientific shams, which nominally serve to *explain* the constitution of the tartrates, but actually to puzzle and bewilder you!

The Xanthates.

A. SULPHOCARBONATES, OR SULPHOXANTHATES.

1.	$H\ ,H\ ,CS^4,S^2$	Hydren xantha sulphene.
2.	ZH^4,ZH^4,CS^4,S^2	Ammonen xantha sulphene.
3.	$K\ ,K\ ,CS^4,S^2$	Potassen xantha sulphene.
4.	$Fe\ ,Fe\ ,CS^4,S^2$	Ferrenous xantha sulphene.
5.	$Fec\ ,Fec\ ,CS^4,S^2$	Ferrenic xantha sulphene.
6.	$C\,H^3,C\,H^3,CS^4,S^2$	Methylen xantha sulphene.
7.	C^2H^5,C^2H^5,CS^4,S^2	Ethylen xantha sulphene.
8.	$K\ ,C^2H^5,CS^4,S^2$	Potassa ethyla xantha sulphene.

B. XANTHATES.

a). Xanthomethylates.

9.	CH^3,CH^3,CS^4O	Methyla methyla xanthate.
10.	$K\ ,CH^3,CS^4O$	Potassa methyla xanthate.
11.	$Pb\ ,CH^3,CS^4O$	Plumba methyla xanthate.

b). Xanthates.

12.	$H\ ,C^2H^5,CS^4O$	Hydra ethyla xanthate.
13.	C^2H^5,C^2H^5,CS^4O	Ethyla ethyla xanthate.
14.	$C\,H^3,C^2H^5,CS^4O$	Methyla ethyla xanthate.
15.	ZH^4,C^2H^5,CS^4O	Ammona ethyla xanthate.
16.	$K\ ,C^2H^5,CS^4O$	Potassa ethyla xanthate.
17.	$Na\ ,C^2H^5,CS^4O$	Natra ethyla xanthate.
18.	$Ba\ ,C^2H^5,CS^4O$	Baryta ethyla xanthate.
19.	$Pb\ ,C^2H^5,CS^4O$	Plumba ethyla xanthate.
20.	$Cu\ ,C^2H^5,CS^4O$	Cuprous ethyla xanthate.

c). *Xanthamylates.*

21.	$H\ ,C^5H^{11},CS^4O$	Hydra amyla xanthate.
22.	$C^5H^{11},C^5H^{11},CS^4O$	Amyla amyla xanthate.
23.	$C\,H^3\ ,C^5H^{11},CS^4O$	Methyla amyla xanthate.
24.	$C^2H^5\ ,C^5H^{11},CS^4O$	Ethyla amyla xanthate.
25.	$ZH^4\ ,C^5H^{11},CS^4O$	Ammona amyla xanthate.
26.	$K\ ,C^5H^{11},CS^4O$	Potassa amyla xanthate.
27.	$Pb\ ,C^5H^{11},CS^4O$	Plumba amyla xanthate.

d). *Xanthopropylates and Xanthocetylates.*

28.	$K,C^3\,H^7\ ,CS^4O$	Potassa propyla xanthate.
29.	$K,C^{16}H^{33},CS^4O$	Potassa cetyla xanthate.

e). *Sulpho-carbamates.*

30.	$H\ ,ZH^2,CS^4$	Hydra amida xantha.
31.	ZH^4,ZH^2,CS^4	Ammona amida xantha.
32.	$Pb\ ,ZH^2,CS^4$	Plumba amida xantha.
33.	$Zn\ ,ZH^2,CS^4$	Zinca amida xantha.
34.	$Cu\ ,ZH^2,CS^4$	Cuprous amida xantha.

C. BINOXYSULPHOCARBONATES.

35.	$C\,H^3\ ,CS^4O$	Methyla xanthate.
36.	$C^2H^5\ ,CS^4O$	Ethyla xanthate.
37.	C^5H^{11},CS^4O	Amyla xanthate.
38.	$ZH^2\ ,CS^4$	Amida xantha.

D. OXYXANTHATES.

39.	$\left\{\begin{matrix} C^2H^5,C^2H^5,CS^4O \\ C^2H^5,C^2H^5,CO^3 \end{matrix}\right\}$	Ethylen xanthate cum ethylen carbite.
40.	$\left\{\begin{matrix} C^2H^5,C^2H^5,CS^4O \\ K\ \ ,K\ \ ,CO^3 \end{matrix}\right\}$	Ethylen xanthate cum potassen carbite.
41.	$\left\{\begin{matrix} C^2H^5,C^2H^5,CS^4O \\ Ag\ ,Ag\ ,CO^3 \end{matrix}\right\}$	Ethylen xanthate cum argenten carbite.
42.	$\left\{\begin{matrix} C^2H^5,C^2H^5,CS^4O \\ Pb\ ,Pb\ ,CO^3 \end{matrix}\right\}$	Ethylen xanthate cum plumben carbite.

E. XANTHAMIDES.

43.	$\left\{\begin{matrix} C^2H^5\ ,C^2H^5\ ,CS^4O \\ ZH^4\ \ \ \ \ \ \ \ ,CNO \end{matrix}\right\}$	Ethylen xanthate cum ammona cyanate.
44.	$\left\{\begin{matrix} C^5H^{11},C^5H^{11},CS^4O \\ ZH^4,\ \ \ \ \ \ \ \ ,CNO \end{matrix}\right\}$	Amylen xanthate cum ammona cyanate.

The compounds that are exhibited in the above Table are those which are produced by the combination of sulphide of carbon with positive radicals, with or without oxygen. The formula which is usually given to sulphide of carbon is CS^2, but in consequence of my having doubled the atomic weight of carbon, I am forced to give to this compound the formula CS^4, and this alteration produces so great a change in the apparent composition of its salts, that I have considered it proper to give a comprehensive series of examples.

Sulphide of carbon appears in this list in the character of an acid radical, and to act in that character, sometimes with bibasic power, and sometimes with monobasic power. The results are convenient for purposes of classification and nomenclature; but I think it right to add, in order to prevent misapprehension, that, in my opinion, the sulphide of carbon is not a radical, but the sulphide of a radical, and ought to be denoted by the formulæ CS^3,S; from which it follows, that the formula for the salt No. 1 ought in strict accuracy to be that of a triple sulphide $= CS^3S + HS + HS$, while the formula for No. 9 ought to represent a double salt $= CH^3,CH^3O + CS^3,S$. This opinion is founded upon the notion, that there exists a series of sulphic vice-radicals which correspond to the vinyl series of hydrogen and chlorine radicals. Thus:

$$\begin{array}{l} CH,\ CH^2,\ CH^3;\ CH^3,H \\ CCl,\ CCl^2,\ CCl^3;\ CCl^3,Cl \\ CS,\ CS^2,\ CS^3;\ CS^3,S. \end{array}$$

But the subject of sulphic radicals is one of such importance and extent that I shall not press it upon the attention of chemists in this article. The formulæ given in the above Table may pass as convenient synoptical formula for the respective salts, while their closer examination is deferred.

I have denoted the sulphide of carbon, CS^4, in these Tables by the term *xanth*. At pages 53, 98, and 109, I wrote *xanthyl*. Upon reconsideration, I think it expedient to leave the terminal *yl* in the exclusive possession of the hydrocarbons.

Xanth, in the state of gas, measures two volumes (see page 53); but the bibasic xanthates also measure two volumes; see three examples at page 60;—hence xanth, like sulphur and carbon, measures nothing in its gaseous salts; and I have so described it at page 109. The measure of two volumes which xanth possesses *per se*, is adverse to the notion that it is a *radical*.

In the following notes, I must quote many of the names that have been applied by chemists to the different kinds of xanthates; but the number of synonymes for these salts to which rival hypotheses respecting their composition have given rise, is so enormous, that I can only give space to a selection from them, and to only a brief notice of the theories upon which they depend. The reader will find ample details respecting the different compounds on consulting the following works:—Gmelin's Handbook of Chemistry, vols. vii, viii, and ix. Gerhardt, Traité de

Chimie, tome 1. Liebig's Handwörterbuch der Chemie, Band iv, article Kohlensulfidsalz; Band v, article Methyloxydsulfokohlensäure; Supplemente, articles Aethersulfokohlensaures Salze, and Amyloxydsulfokohlensäure.

GROUP A. *Sulphocarbonates.*

The salt No. 2 is prepared by dissolving bisulphide of carbon in a solution of sulphide of ammonium. $\mathrm{ZH^4,S + ZH^4,S + CS^4}$. The acid No. 1 is prepared by acting upon the salt No. 2 with hydrochloric acid:

$$\mathrm{ZH^4,ZH^4,CS^4,S^2 + HCl,HCl = H,H,CS^4,S^2 + ZH^4Cl,ZH^4Cl.}$$

Diluted solutions of these salts when exposed to the air are rapidly decomposed, carbonates being formed and sulphur precipitated:

$$\mathrm{K,K,CS^4,S^2 + O^3 = KK,CO^3 + S^6.}$$

Concentrated solutions, when mixed with strong acids, are decomposed, producing the acid No. 1:

$$\mathrm{K,K,CS^4S^2 + HCl,HCl = H,H,CS^4,S^2 + KCl,KCl.}$$

Besides the salts that are named in the Table from Nos. 1 to 8, similar compounds have been formed with $\mathrm{Na^2}$, $\mathrm{Ba^2}$, $\mathrm{Sr^2}$, $\mathrm{Ca^2}$, $\mathrm{Li^2}$, $\mathrm{Crc^2}$, $\mathrm{Uc^2}$, $\mathrm{Auc^2}$, $\mathrm{Sn^2}$, $\mathrm{Snc^2}$, $\mathrm{Hg^2}$, $\mathrm{Hgc^2}$. Consequently, the basylous and basylic atoms are acted upon by $\mathrm{CS^4}$ *equally.*

Usual names. 1]. Hydrosulphocarbonic acid. Trisulphocarbonic acid. Hydrothiocarbonsäure. 2]. Hydrosulphocarbonate of ammonia. Kohlensulfid-ammonium. 3]. Sulphocarbonate of potassium. Kohlensulfid-kalium. Kalium-sulfocarbonat. Hydrothiocarbonsaures kali. The names of No. 3 may serve as patterns of those of all the salts which have M,M as radicals. I shall point out the formulæ which distinguish the salts that contain basylic atoms.

	Common Formulæ.	Proposed Formulæ.
Ferrous atoms . .	$\mathrm{FeS\ .\ CS^2}$	$\mathrm{Fe\ ,Fe\ ,CS^4,S^2.}$
Ferric atoms . .	$\mathrm{Fe^2S^3 .3CS^2}$	$\mathrm{Fec,Fec\ ,CS^4,S^2.}$
Chromic atoms . .	$\mathrm{Cr^2S^3 .3CS^2}$	$\mathrm{Crc\ ,Crc\ ,CS^4,S^2.}$
Auric atoms . .	$\mathrm{Au^2S^3.3CS^2}$	$\mathrm{Auc,Auc,CS^4,S^2}$
Mercurous atoms .	$\mathrm{Hg^2S\ .\ CS^2}$	$\mathrm{Hg\ ,Hg\ ,CS^4,S^2}$
Mercuric atoms . .	$\mathrm{HgS\ .\ CS^2}$	$\mathrm{Hgc,Hgc,CS^4,S^2}$
Uric atoms . . .	$\mathrm{U^2S^3\ .\ CS^2}$	$\mathrm{Uc\ ,Uc\ ,CS^4,S^2}$
Stannous atoms . .	$\mathrm{SnS\ .\ CS^2}$	$\mathrm{Sn\ ,Sn\ ,CS^4,S^2}$
Stannic atoms . .	$\mathrm{SnS^2 .2CS^2}$	$\mathrm{Snc\ ,Snc\ ,CS^4,S^2}$

There is here a striking contrast between the *regularity* of the proposed formulæ, and the *irregularity* of the common formulæ. There can be no pretension here, any more than among the cyanides, that the difference is attributable to the presence of protoxides and peroxides, and therefore these examples show the absurdity of the commonly-received atomic weights, and justify the adoption of basylic as well as basylous atoms. See page 32.

6]. Sulphocarbonate of methyl. Trisulphocarbonate of methyl. Sulfocarbonate de sulfure de methyle. Schwefelkohlenstoff-Schwefel-Formafer. Kohlensulfid-methyl. Methylic sulphocarbonate. 7]. Similar to No. 6. 8]. Sulphoxanthate of potassium. Trisulphuretted carbovinate of potash. Ethyl-trisulphocarbonate of potash. A conjugated acid corresponding to No. 8 is described in the books = H,C^2H^5,CS^4,S^2, but no such acid exists. The salt No. 6 produces a gas, the measure of which is two volumes. See page 60.

GROUP B. *Xanthates.*

a). *Xanthomethylates.* According to organic chemists, the foundation of this group of salts is an acid of the following constitution H,CH^3,CS^4O, and which has received the following very fine names: Holz-Xanthonsäure. Holz-xanthogensäure. Methyl-schwefelkohlensäure. Methyloxydsulfokohlensäure. Methyl-xanthonsäure. Acide méthyl-xanthique. Acide méthyl-disulfocarbonique. Acide sulfocarbomethylique. Xanthomethylic acid. Methyl-disulphocarbonic acid. Sulphocarbomethylic acid. Methylxanthic acid. Unluckily, this many-named acid does not exist. What a pity it is, that so much excellent nomenclature should be wasted! The salts Nos. 10 and 11 have names that correspond in euphony and explicitness with the names of the unknown "acid." No. 9] has some special names. Methyl-xanthic ether. Schwefelkohlenstoff-Formester. Sulphocarbonate of methyl-oxide. Disulphocarbonate of methyl. Kohlensulfid-methyloxyd. Methyl-oxysulfocarbonat. Gmelin's formula for it is C^2H^3O,CS^2. Gerhardt's formula is $C^2S^4\left\{\begin{matrix}C^2H^6O\\C^2H^6O\end{matrix}\right.$. Dumas's formula is $C^2H^3O,CS^2 + HO,CS^2$. Berzelius's formula is $C^2H^3O.CO^2 + 2(C^2H^3S.CS^2)$. The last formula arranged on the plan of my Table, after correcting the atomic weights of C and O, becomes

$$\begin{Bmatrix}CH^3,CH^3,CS^4,S^2\\CH^3,CH^3,CS^4,S^2\\CH^3,CH^3,C\quad O^3\end{Bmatrix}$$

But if all the substances here represented are divided by 3, this great formula is reduced to No. 9. The proof that it ought to be so reduced lies in the fact, that the salt is gaseous, and has an atomic measure of two volumes, which is the bulk of two atoms of CH^3, the xanth and oxygen measuring nothing. See page 60.

b). *Xanthates.* The salts of this group, Nos. 12 to 20, differ from those of the preceding group merely by containing ethyl instead of methyl. They constitute the xanthates proper, and were discovered earlier, and are better known, than the salts in groups *a*), *c*), *d*), and *e*).

Nomenclature :—12]. Xanthic acid. Sulphocarbonic acid. Sulphocarbovinic acid. Sulphocarbéthénic acid. Aetherschwefelkohlensäure. Xanthogensäure. Xanthonsäure. Xanthinsäure. Hydroxanthinsäure. Aethyloxyd-Bisulfocarbonat. Saures Aethyloxysulfocarbonat, *Berzelius.* Kohlenschwefelsaures Aethyloxydhydrat, *Liebig.* Acide éthyl-disulfo carbonique, *Gerhardt.* *Formulæ*: $C^4H^6O^2,2CS^2$, *Gmelin.* $C^2S^4(C^4H^5O + HO)$, *Gerhardt.* $C^4H^5O.CS^2 + HO.CS^2$, *Zeise.* $(C^4H^5O.CO^2 + HO.CO^2) + 2(C^4H^5S.CS^2 + HS.CS^2$, *Berzelius.*

$$C^4H^5O.C\left\{\begin{matrix}O\\S\end{matrix}\right. + HS.CS^2,\ \textit{Kolbe.}$$

The variety of the names and the intricacy of the formulæ of this "acid" sufficiently indicate the diversity of opinions that have prevailed among chemists respecting the constitution of the salts to which it belongs. Absolute certainty on the subject is unattainable, and conjectures can be multiplied indefinitely. If xanth was certainly an acid radical, there would be little difficulty, for then we might say in H,M,CS^4O, we have clearly a bibasic salt. But I do not believe that CS^4 is a radical. Its atomic measure of two volumes is adverse to that supposition. Taking xanth to be a sulphide $= CS^3,S$, we are still in doubts respecting the composition of the xanthates, for we may formulate No. 12

$$\text{as}\left\{\begin{matrix}H\ ,C^2H^5O\\CS^3,S\end{matrix}\right\},\text{ or}\left\{\begin{matrix}H\ ,CS^3O\\C^2H^5,S\end{matrix}\right\},\text{ or}\left\{\begin{matrix}C^2H^5,CS^3\\H\ ,SO\end{matrix}\right\},\text{ or}\left\{\begin{matrix}C^2H^5,CS^3O\\H\ ,\ S\end{matrix}\right\},\ \&c.$$

The accuracy of these formulæ admits neither of proof nor disproof, and therefore I have rested, at present, upon the formula No. 12, which serves, at any rate, to form a central point around which the different varieties of xanthates can be grouped, while we wait for more exact information respecting their intimate nature.

13]. Kohlensulfid-Aethyloxyd. Schwefelkohlenstoffaether. Aethyloxysulfocarbonat. Ether xanthique. Disulfocarbonate d'éthyle. Oxysulphocarbonate of ethyl. Xanthic ether. Aethyloxydschwefelkohlenstoff. Schwefelkohlenstoffvinester. Xanthonsaures Aethyloxyd. Ether sulfocarbonique.

14]. Vinomethylic Oxysulphocarbonate. Carbométhylovinide bisulfuré. Zweifach-geschwefeltes Carbomethylovinid. Disulfocarbonate d'éthyle et de méthyle. Vinomethylic carbonate. Xanthate of methyl. Xanthomethylate of ethyl. No. 14 is a gas, having an atomic measure of two volumes. See page 60.

I will not trouble the reader with the synonymes of the salts Nos. 15 to 20, but in regard to the names of the entire group, I wish him to observe the simplicity and perfect regularity in the composition of the salts as exhibited by the formulæ from Nos. 12 to 20, and then to compare these qualities with the strange complexity and irregularity of the names that I have quoted as employed by eminent chemists to designate the salts Nos. 12, 13, and 14. Surely, there is evidence *here* of the want of a PRINCIPLE in chemical nomenclature by which chemists might be guided in forming names for the salts which they discover.

The potash salt No. 16, is formed by the direct action of sulphide of carbon upon a solution of hydrate of potash in absolute alcohol. This reaction agrees extremely well with the formula:

$$\mathrm{K,C^2H^5O} \quad + \quad \mathrm{CS^4} \;=\; \mathrm{K,C^2H^5,CS^4O}.$$

Potash in alcohol + xanth = xanthate of potash.

c). *Xanthamylates.* As the salts Nos. 21 to 27 differ from the preceding groups only by the replacement of CH^3, or C^2H^5, by C^5H^{11}, it is needless to go into details respecting them. I will however quote a single set of names and formulæ for three examples, as given by a chemist who has investigated them, (Johnson, *Quarterly Journal of the Chemical Society* (1852), v. 142).

23].	$\begin{pmatrix}\mathrm{C^2\,H^3}\\ \mathrm{C^{10}H^{11}}\end{pmatrix} \mathrm{2CS^2O}.$	Sulphocarbonate of methyl and amyl.
24].	$\begin{pmatrix}\mathrm{C^{10}H^{11}.CS^2O}\\ \mathrm{C^4\,H^5\,.CS^2O}\end{pmatrix}.$	Sulphocarbonate of amyl and ethyl.
25].	$\mathrm{H^4N.C^{10}H^{11},2CS^2O}.$	Amyloxanthate of ammonia.

Here, in describing three equivalent salts, we have three changes in formulæ and two changes in nomenclature. Why?

d]. *Xanthopropylates and Xanthocetylates.* 28]. Propyloxanthate of potash, *Chancel.* 29]. Potash salt of Acide cétyl-disulfocarbonique, *Desains.* There are, in chemical books, descriptions of imaginary conjugated acids corresponding to both these salts.

e). *Sulphocarbamates.* Nos. 30 to 34. The fundamental salt of this series is No. 31 = ZH^4,ZH^2,CS^4. Gerhardt calls this salt the sulpho carbamate of ammonia, and gives it the formula $C^2H^2(NH^4)NS^4$. Kolbe's name and formula are Sulfocarbamidsaures Ammoniumsulfuret $NH^4S.C(SNH^2),CS^2$. The salt is produced from the ammonium salt No. 2] by the abstraction of two atoms of HS. We may also consider the series 30 to 34, as amidogen salts of the xanthic series; for if HHO was added to each salt, we should have, for example,

No. 30 raised to $\mathrm{H\ ,ZH^4,CS^4O}$.
32 „ $\mathrm{Pb,ZH^4,CS^4O}$.

We have indeed no knowledge of ammonium salts that are constituted in agreement with these formulæ; but they may probably be found if looked for.

C. BINOXYSULPHOCARBONATES.

35]. Binoxysulphocarbonate of methyl. Persulfure méthyl-disulfo carbonique

$$= \begin{matrix} C^2O^4 \\ C^2S^4 \end{matrix} \left\{ \begin{matrix} C^2H^3S^2 \\ C^2H^3S^2 \end{matrix} \right., \textit{ Gerhardt.}$$

36]. Binoxysulphocarbonate of ethyl, *Desains*. Persulfure éthyl-disulfocarbonique

$$= \begin{matrix} C^2O^4 \\ C^2S^4 \end{matrix} \left\{ \begin{matrix} C^4H^5S^2 \\ C^4H^5S^2 \end{matrix} \right., \textit{ Gerhardt.}$$

37]. Binoxysulphocarbonate of amyl = $C^{10}H^{11}.2CS^2O$, *Johnson*. Persulfure amyl-disulfocarbonique

$$= \begin{matrix} C^2O^4 \\ C^2S^4 \end{matrix} \left\{ \begin{matrix} C^{10}H^{11}S^2 \\ C^{10}H^{11}S^2 \end{matrix} \right., \textit{ Gerhardt.}$$

No. 36 is produced by the action of iodine upon the salt No. 16. Thus:

$$K,C^2H^5,CS^4O + I = KI + C^2H^5,CS^4O.$$

The group of salts C, as compared with those of Group B, present the peculiarity, that the same acid radical with the same quantity of oxygen is in one case monobasic, and in the other bibasic. I have pointed out several examples of this peculiarity in treating of the polythionates; where I have shown that this effect, though apparent, is unreal. See page 173. A similar interpretation is probably due in this case; so that methyloxanthate, instead of being a simple salt, as represented by formula 35, may be, in fact, a double salt, or compound of two salts, whereof one may be oxidised, and the other not oxidised. For example, $CH^2,SO + CS^2,S$.

This explanation implies the existence of a vice-radical of the form CS^2, namely, one that is equal to vinyl CH^2, but having the hydrogen replaced by sulphur. There is no argument to urge against the probability of the existence of such a vice-radical, but I can adduce no facts to support it. In the meantime, I represent the binoxysulphocarbonates as monobasic xanthates.

38]. This is the amidogen salt of this series, derived from the unknown ammonium salt ZH^4,CS^4O. The ordinary names of this amidogen salt are Hydranzothine, Bihydrosulphuretted sulphocyanogen, Bisulphide of sulphocarbammonium, Doppelt-Schwefelwasserstoff-Schwefelcyan, all of which conceal the nature of the substance as much as they can.

D. OXYXANTHATES.

39]. Carbonate of sulphethyl, or carbonate of ethylic sulphide = C^4H^5S,CO^2, *Gmelin*. Sulphocarbonate of ethyle, or carbonate of sulphide of ethyle = $C^2O^4 \left\{ \begin{matrix} C^4H^5S \\ C^4H^5S \end{matrix} \right.$. 40]. Oxyxanthate of potassium = $C^4H^5KS^2,2CO^2$, *Gmelin*. Kohlensaures Aethyl - Kaliumsulfuret, *Debus.* Ethyl sulphocarbonate of potash $= C^2O^4 \left\{ \begin{matrix} C^4H^5S \\ K\,S \end{matrix} \right.$, *Gerhardt.*

41] and 42]. Similar names to those of Nos. 39 and 40.

The formulæ in the Table Nos. 39 to 42 appear to be justified by the following reaction:

Xanthic ether No. 13, dissolved in alcohol, and mixed with an alcoholic solution of hydrate of potash, produces oxyxanthate of potash No. 40, and mercaptan.

$$13] = \left. \begin{matrix} C^2H^5,C^2H^5,CS^4O \\ C^2H^5,C^2H^5,CS^4O \\ K\,,HO \\ K\,,HO \end{matrix} \right\} = \left\{ \begin{matrix} \left. \begin{matrix} C^2H^5,C^2H^5,CS^4O \\ K\,,\quad K\,,C\quad O^3 \end{matrix} \right\} = 40]. \\ H\,,C^2H^5,S^2 \\ H\,,C^2H^5,S^2 \end{matrix} \right.$$

Nevertheless, it will be observed, that the formula No. 40 is divisible into two equal parts, thus:

$$\left. \begin{matrix} C^2H^5,C^2H^5,CS^4O \\ K\,,\quad K\,,C\quad O^3 \end{matrix} \right\} = \left\{ \begin{matrix} K,C^2H^5,CS^2O^2 \\ K,C^2H^5,CS^2O^2 \end{matrix} \right.$$

And, secondly, that this formula agrees equally well with the reaction just described. Thus:

$$\begin{matrix} C^2H^5,C^2H^5,CS^4O \\ K\,,H\quad O \end{matrix} = \begin{matrix} K,C^2H^5,CS^2O^2 \\ H,C^2H^5,\ S^2 \end{matrix}$$

In the formula K,C^2H^5,CS^2O^2, we have again the radical CS^2 to which I have before referred, and here it appears to act as a bibasic acid radical with two atoms of oxygen. Though I am inclined to admit the compound CS^2 to be a radical, yet I am not of opinion that it can be bibasic, and therefore I adhere to the formulæ quoted in the Table, which represent each salt as consisting of a carbonate combined with a xanthate, as being probable though complicated.

Group E. XANTHAMIDES. Nos. 43 and 44. If we suppose a salt of Group D to contain ammonium, and that salt to be deprived of two atoms of water, we should have the residue expressed in the following equation:

$$\left. \begin{matrix} C^2H^5,C^2H^5,CS^4O \\ ZH^4\,,ZH^4\,,C\quad O^3 \end{matrix} \right\} = \left\{ \begin{matrix} \left. \begin{matrix} C^2H^5,C^2H^5,CS^4O \\ ZH^2\,,ZH^2\,,C\quad O \end{matrix} \right\} \text{Residue.} \\ H^2,\quad H^2,\qquad O^2 = Aq^2. \end{matrix} \right.$$

That portion of the compound amidogen salt which is represented by ZH^2,ZH^2,CO is carbamide, of which I have treated fully at pages 221, 338, and 359, where I have advanced arguments that I imagine will justify the formulæ which I have now given to the Xanthamides.

Usual names. 43]. Xanthamide. Xanthogenamid. $C^6NH^7S^2O^2$

$= C^4AdH^5 \left\{ \begin{matrix} CS^2 \\ CO^2 \end{matrix} \right.$. $=$ Xd. *Gmelin.* $= C^4H^6S^2,C^2HNO^2$

$$= 3C^4H^6S^2,C^6H^3N^3O^6 = C^4H^5O,C^2NH^2O.CS^2$$
$$= C^4H^5O,C^2NH^2O,CO^2 + C^4H^5S,C^2NH^2S,CS^2,$$

Debus (in *Gmelin's Handbook of Chemistry*, ix. 277). Sulphocarbamate of ethyle. Uréthane sulfurée = $\left.\begin{matrix} NH^2(CO)^2S \\ C^4H^5S \end{matrix}\right\}$, *Gerhardt*.

It would be difficult to determine what particular *meaning*, if any, the various authors attached to these singular groups of symbols.

Preparation of Xanthamide. "Dry ammoniacal gas is passed into an alcoholic solution of bioxysulphocarbonate of ethyl" [No. 36], "whereupon the liquid becomes hot, and yields a precipitate of sulphur. As soon as this precipitation is at an end, the passage of the gas is interrupted, the liquid filtered, and the filtrate evaporated to dryness in vacuo. The residue effloresces almost completely, forming small aggregated crystals of xanthate of ammonia" [No. 15] "saturated with an oily liquid which is xanthamide," *Gmelin*.

$$\underbrace{\begin{matrix} C^4H^5,CS^4O \\ C^4H^5,CS^4O \\ C^4H^5,CS^4O \end{matrix}}_{\text{No. 36.}} + \left.\begin{matrix} ZH^2,H \\ ZH^2,H \\ ZH^2,H \end{matrix}\right\}_{\text{Ammonia.}} = \left\{\begin{matrix} Z\,H^4,C^4H^5,CS^4O & = \text{No. 15.} \\ \left.\begin{matrix} C^4H^5,C^4H^5,CS^4O \\ Z\,H^4, \quad CN\,O \end{matrix}\right\} & = \text{No. 43.} \end{matrix}\right.$$

44]. Sulphocarbamate of amyle = $\left.\begin{matrix} NH^2(CO)^2S \\ C^{10}H^{11}S \end{matrix}\right\}$, *Gerhardt*. Xanthamylamide = $C^{12}H^{13}NO^2S^2$, *Johnson*. Obtained by the action of ammonia on the salt No. 37. The explanation is the same as that just given of the process for preparing No. 43.

The only thing that prevents the formation of simple and exact formulæ for the different orders of xanthates, is the want of a precise knowledge of the proximate constitution of the sulphide of carbon. Until that knowledge is obtained, all possible formulæ for its salts must be subject to uncertainty. Yet the salts are so simple, so regular, and so evidently related to one another in groups, that there is no excuse for the wild extravagance of the names by which they all are commonly designated. In the construction of these names there has been a total disregard, not only of scientific order but of common intelligence. In only one particular can they be considered to be successful, which is, in effectually concealing the information which they profess to carry. It would be scarcely possible to pick out from among them a single name after which an impartial student of chemistry could undertake to write a formula of the salt to which it refers. That result infers the arrival at a degree of perfection in the art of concealing knowledge which I reckon to be the *ne plus extra* of non-scientific nomenclature.

The Conjugated Sulpho-Acids.

Under the head of Conjugated Sulpho-Acids, I propose to give some account of the salts that are produced by the action of sulphuric acid upon compound organic radicals. Many of these salts have already passed incidentally under our notice in the review of other groups of salts; but it is still necessary to give them a formal and systematic examination, partly that I may place the subject before the reader in a complete state, and partly that I may be able to supply corrections which recent discoveries have rendered it necessary to make in preceding statements.

I propose, now, when interpreting the proximate constitution of the conjugated sulpho-acids, to avail myself of the fact which I first pointed out at page 376, namely, that when a radical which, under ordinary circumstances, acts the part of an ACID *radical*, goes into a salt in the character of a BASIC *radical*, it carries with it an additional quantity of *Oxygen*. I have said at page 376, that it takes with it *one additional atom* of oxygen; but I must correct that expression. When the radical belongs to the vinyl series, or to any series which produces normal salts with O^2, then the transferable quantity of oxygen is indeed O^1; but when the radical belongs to those which produce normal salts with O^3, then the transferable quantity of oxygen is O^2. Hence it is, that the composition of the nitric acid anhydride is N,NO^5, that of the phosphoric acid anhydride P,PO^5, and that of the tartaric acid anhydride C^2H^2, $C^2H^2O^5$.

I regret to have to repeat here, what I have stated at page 377, that I cannot point out which are the radicals that act as transporters of oxygen into salts, and which do not so act. I am unable to draw a clear line of distinction between them. Generally speaking, all the acid radicals of the vinyl series, and many of those which belong to the series $nCH^2 - H^9$, take up O^1 additional when they act as basic radicals. On the other hand, phenyl and most of the radicals of the series $nCH^2 - H^7$, act as basic radicals without taking up additional oxygen. A few radicals of frequent occurrence, such as benzyl, sometimes take up additional oxygen, and sometimes, in circumstances apparently similar, dispense with it. These anomalies may hereafter disappear. In the meantime, the main fact, that certain acid radicals take up O^1 or O^2 extra, when they pass into salts to act as basic radicals, is so certain, and leads to such remarkable elucidations of difficult theoretical points, that the nature and extent of the action demand a thorough investigation.

BISULPHATES OF BASIC RADICALS.

Group A. *Bisulphates with Radicals of the Vinyl Series.*

1. $\left\{\begin{matrix}\mathrm{C\,H^3,SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Methyla sulphete cum hydra sulphete.

2. $\left\{\begin{matrix}\mathrm{C^2H^5,SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Ethyla sulphete cum hydra sulphete.

3. $\mathrm{C^2H^5,SO^2 + Pb\,,SO^2}$ Ethyla sulphete cum plumba sulphete.

4. $\left\{\begin{matrix}\mathrm{C^2H^5,SO^2 + H\,,SO^2}\\ \mathrm{C^2H^5,SO^2 + Pb\,,SO^2}\end{matrix}\right\}$ Ethyla sulphete cum hydra sulphete plus ethyla sulphete cum plumba sulphete.

5. $\left\{\begin{matrix}\mathrm{C^2H^5,SO^2 + Pb\,,SO^2}\\ \mathrm{C^2H^5,SO^2 + Pb^3,SO^3}\end{matrix}\right\}$ Ethyla sulphete cum plumba sulphete plus ethyla sulphete cum plumbine sulphite.

6. $\left\{\begin{matrix}\mathrm{C^3H^7\,,SO^2}\\ \mathrm{Ba\,,SO^2}\end{matrix}\right\}$ Propyla sulphete cum baryta sulphete.

7. $\left\{\begin{matrix}\mathrm{C^4H^9\,,SO^2}\\ \mathrm{K\,,SO^2}\end{matrix}\right\}$ Butyla sulphete cum potassa sulphete.

8. $\left\{\begin{matrix}\mathrm{C^5H^{11},SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Amyla sulphete cum hydra sulphete.

9. $\left\{\begin{matrix}\mathrm{C^8H^{17},SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Octyla sulphete cum hydra sulphete.

10. $\left\{\begin{matrix}\mathrm{C^{16}H^{33},SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Cetyla sulphete cum hydra sulphete.

Group B. *Bisulphates with Radicals not of the Vinyl Series.*

11. $\left\{\begin{matrix}\mathrm{C^6\,H^5\,,SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Phenyla sulphete cum hydra sulphete.

12. $\left\{\begin{matrix}\mathrm{C^6\,H^5\,,SO^2}\\ \mathrm{C\,H^3\,,SO^2}\end{matrix}\right\}$ Phenyla sulphete cum methyla sulphete.

13. $\left\{\begin{matrix}\mathrm{C^6\,H^5\,,SO^2}\\ \mathrm{CH^2Ba,SO^2}\end{matrix}\right\}$ Phenyla sulphete cum barytic-methyla sulphete.

14. $\left\{\begin{matrix}\mathrm{C^{10}H^{13}\,,SO^2}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Thymyla sulphete cum hydra sulphete.

15. $\left\{\begin{matrix}\mathrm{C^{10}H^{13}\,,SO^2}\\ \mathrm{Ba\,,SO^2}\end{matrix}\right\}$ Thymyla sulphete cum baryta sulphete.

BISULPHATES OF ACID RADICALS.

Group A. *Bisulphates containing Radicals of the Vinyl Series.*

16. $\left\{\begin{matrix}\mathrm{H,C^2H^3O^2}\\ \mathrm{(H,SO^2)^2}\end{matrix}\right\}$ Hydra acetylete bis hydra sulphete.

17. $\left\{\begin{matrix}\mathrm{C^2\,H^3\,,SO^3}\\ \mathrm{H\,,SO^2}\end{matrix}\right\}$ Acetyla sulphite cum hydra sulphete.

18. $\left\{\begin{array}{ll} C^2H^2Ba & ,SO^3 \\ Ba & ,SO^2 \end{array}\right\}$ Barytic-acetyla sulphite cum baryta sulphete.

19. $\left\{\begin{array}{ll} H & ,C^2H^3O^2 \\ (Ba & ,\ SO^2)^2 \end{array}\right\}$ Hydra acetylete bis baryta sulphete.

19*a*. $\left\{\begin{array}{ll} C^2H^3 & ,SO^3 \\ HBa^2 & ,SO^3 \end{array}\right\}$ Acetyla sulphite cum hydra baryten sulphite.

20. $\left\{\begin{array}{ll} C^2H^2Ag & ,SO^3 \\ Ag & ,SO^2 \end{array}\right\}$ Argentic-acetyla sulphite cum argenta sulphete.

21. $\left\{\begin{array}{ll} C^3H^4Ba & ,SO^3 \\ Ba & ,SO^2 \end{array}\right\}$ Barytic-propionyla sulphite cum baryta sulphete.

22. $\left\{\begin{array}{ll} C^3H^5 & ,SO^3 \\ H & ,SO^2 \end{array}\right\}$ Propionyla sulphite cum hydra sulphete.

23. $\left\{\begin{array}{ll} ZH^3,C^3H^5 & ;\ SO^3 \\ ZH^4 & ,SO^2 \end{array}\right\}$ Propionylam sulphite cum ammona sulphete.

24. $\left\{\begin{array}{ll} C^4H^6Ba & ,SO^3 \\ Ba & ,SO^2 \end{array}\right\}$ Barytic-butyryla sulphite cum baryta sulphete.

25. $\left\{\begin{array}{ll} C^4H^7 & ,SO^3 \\ H & ,SO^2 \end{array}\right\}$ Butyryla sulphite cum hydra sulphete.

Group B. *Bisulphates containing Benzyl.*

26. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ H & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum hydra sulphete.

27. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ Ba & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum baryta sulphete.

28. $\left\{\begin{array}{ll} C^7H^4Ba & ,SO^3 \\ Ba & ,SO^2 \end{array}\right\}$ Barytic-benzyla sulphite cum baryta sulphete.

29. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ Ag & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum argenta sulphete.

30. $\left\{\begin{array}{ll} C^7H^4Ag & ,SO^3 \\ Ag & ,SO^2 \end{array}\right\}$ Argentic-benzyla sulphite cum argenta sulphete.

31. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ C^2H^5 & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum ethyla sulphete.

32. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ ZH^3,C^2H^5 & ;\ SO^2 \end{array}\right\}$ Benzyla sulphite cum ethylam sulphete.

33. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ C^2H^4Na & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum natric-ethyla sulphete.

34. $\left\{\begin{array}{ll} C^7H^5 & ,SO^3 \\ C^2H^4Ba & ,SO^2 \end{array}\right\}$ Benzyla sulphite cum barytic-ethyla sulphete.

Group C. *Bisulphates containing Anisyl, Cinnamyl, or Spiryl.*

35. $\left\{\begin{array}{ll} H & ,C^8H^7O^2 \\ (H & ,\ SO^2)^2 \end{array}\right\}$ Hydra anisylite bis hydra sulphete.

36. $\left\{\begin{array}{ll} H & ,C^8H^7O^3 \\ (Ba & ,\ SO^2)^2 \end{array}\right\}$ Hydra anisylite bis baryta sulphete.

37. $\left\{\begin{array}{ll} H & ,C^8H^7O^3 \\ (Pb & ,\ SO^2)^2 \end{array}\right\}$ Hydra anisylite bis plumba sulphete.

38. $\left\{\begin{array}{ll} C^8H^7 & ,\ SO^4 \\ H & ,\ SO^2 \end{array}\right\}$ Anisyla sulphote cum hydra sulphete.

39. $\left\{\begin{array}{ll} C^8H^6Ba, & SO^4 \\ Ba & ,\ SO^2 \end{array}\right\}$ Barytic-anisyla sulphote cum baryta sulphete.

40. $\left\{\begin{array}{ll} C^8H^6Pb, & SO^4 \\ Pb & ,\ SO^2 \end{array}\right\}$ Plumbic-anisyla sulphote cum plumba sulphete.

41. $\left\{\begin{array}{ll} C^9H^7 & ,\ SO^3 \\ H & ,\ SO^2 \end{array}\right\}$ Cinnamyla sulphite cum hydra sulphete.

42. $\left\{\begin{array}{ll} C^9H^6Ag, & SO^3 \\ Ag & ,\ SO^2 \end{array}\right\}$ Argentic-cinnamyla sulphite cum argenta sulphete.

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43. $\left\{\begin{array}{ll} C^7H^5 & ,\ SO^4 \\ H & ,\ SO^2 \end{array}\right\}$ Spiryla sulphote cum hydra sulphete.

DOUBLE HYPOSULPHATES.

Group A. *Hyposulphates containing Radicals of the Vinyl Series.*

44. $\left\{\begin{array}{ll} CH^3 & ,\ S^2O^3 \\ H & ,\ S^2O^3 \end{array}\right\}$ Methyla sulphenite cum hydra sulphenite.

45. $\left\{\begin{array}{ll} CH^2Ba & ,\ S^2O^3 \\ Ba & ,\ S^2O^3 \end{array}\right\}$ Barytic-methyla sulphenite cum baryta sulphenite.

46. $\left\{\begin{array}{ll} CH^2Ag & ,\ S^2O^3 \\ Ag & ,\ S^2O^3 \end{array}\right\}$ Argentic-methyla sulphenite cum argenta sulphenite.

47. $\left\{\begin{array}{ll} ZH^2,CH^3; & S^2O^3 \\ ZH^4 & ,S^2O^3 \end{array}\right\}$ Methylam sulphenite cum ammona sulphenite.

48. $\left\{\begin{array}{ll} C^2H^5 & ,S^2O^3 \\ H & ,S^2O^3 \end{array}\right\}$ Ethyla sulphenite cum hydra sulphenite.

49. $\left\{\begin{array}{ll} C^2H^4Ba & ,S^2O^3 \\ Ba & ,S^2O^3 \end{array}\right\}$ Barytic-ethyla sulphenite cum baryta sulphenite.

50. $\left\{\begin{array}{ll} ZH^2,C^2H^5; & S^2O^3 \\ ZH^4 & ,S^2O^3 \end{array}\right\}$ Ethylam sulphenite cum ammona sulphenite.

51. $\left\{\begin{array}{ll} C^3H^7 & ,S^2O^3 \\ H & ,S^2O^3 \end{array}\right\}$ Propyla sulphenite cum hydra sulphenite.

52. $\left\{\begin{array}{ll} C^3H^6Ba & ,S^2O^3 \\ Ba & ,S^2O^3 \end{array}\right\}$ Barytic-propyla sulphenite cum baryta sulphenite.

GROUP B. *Hyposulphates containing Phenyl.*

53. $\left\{\begin{array}{ll} C^6H^5 & ,S^2O^3 \\ H & ,S^2O^3 \end{array}\right\}$ Phenyla sulphenite cum hydra sulphenite

54. $\left\{\begin{matrix} C^6H^4Ba & ,S^2O^3 \\ Ba & ,S^2O^3 \end{matrix}\right\}$ Barytic-phenyla sulphenite cum baryta sulphenite.

GROUP C. *Hyposulphates containing Naphtyl.*

55. $\left\{\begin{matrix} C^{10}H^7 & ,S^2O^3 \\ H & ,S^2O^3 \end{matrix}\right\}$ Naphtyla sulphenite cum hydra sulphenite.

56. $\left\{\begin{matrix} C^{10}H^6Ba & ,S^2O^3 \\ Ba & ,S^2O^3 \end{matrix}\right\}$ Barytic-naphtyla sulphenite cum baryta sulphenite.

GROUP D. *Hyposulphates containing Anisol.* (*Toluenyl?*)

57. $\left\{\begin{matrix} C^7H^7 & ,S\,O^2 + Ba,SO^2 \\ H & ,S\,O^2 + Ba,SO^2 \end{matrix}\right\}$ Toluenyla sulphete cum hydra sulphete bis baryta sulphete.

58. $\left\{\begin{matrix} C^7H^6Ba & ,S^2O^4 \\ Ba & ,S^2O^3 \end{matrix}\right\}$ Barytic-toluenyla sulphenote cum baryta sulphenite.

59. $\left\{\begin{matrix} C^7H^7 & ,S^2O^4 \\ H & ,S^2O^3 \end{matrix}\right\}$ Toluenyla sulphenote cum hydra sulphenite.

Group E. *Amidogen Hyposulphates.*

60. $\left\{\begin{matrix} ZH,C^6H^5 & ; S^2O^3 \\ H & ; S^2O^3 \end{matrix}\right\}$ Phenylac sulphenite cum hydra sulphenite.

61. $\left\{\begin{matrix} ZBa,C^6H^5 & ; S^2O^3 \\ Ba, & ; S^2O^3 \end{matrix}\right\}$ Barytic-phenylac sulphenite cum baryta sulphenite.

62. $\left\{\begin{matrix} ZAg,C^6H^5 & ; S^2O^3 \\ Ag & ; S^2O^3 \end{matrix}\right\}$ Argentic phenylac sulphenite cum argenta sulphenite.

63. $\left\{\begin{matrix} ZH,C^6H^5 & ; S^2O^3 \\ ZH^2 & ; S^2O^3 \end{matrix}\right\}$ Phenylac sulphenite cum amida sulphenite.

64. $\left\{\begin{matrix} ZH,C^6H^5 & ; S^2O^3 \\ ZBa^2 & ; S^2O^3 \end{matrix}\right\}$ Phenylac sulphenite cum barytec sulphenite.

SULPHITES.

Group A. *Sulphites containing Radicals of the Vinyl Series.*

65. $H\ ;\ C\,H^3\ ;\ S^2O^3$ Hydra methyla sulphenite.
66. $Ba\ ;\ C\,H^3\ ;\ S^2O^3$ Baryta methyla sulphenite.
67. $Ag\ ;\ C\,H^3\ ;\ S^2O^3$ Argenta methyla sulphenite.
68. $Pb\ ;\ C\,H^3\ ;\ S^2O^3$ Plumba methyla sulphenite.
69. $\left\{\begin{matrix} Pb^3\ ;\ C\,H^3\ ;\ S^2O^4 \\ = CH^3,SO + Pb^3.SO^3 \end{matrix}\right.$ Plumbine methyla sulphenote / Methyla sulphate cum plumbine sulphite.
70. $K\ ;\ C\,H^3\ ;\ S^2O^3$ Potassa methyla sulphenite.
71. $\left\{\begin{matrix} K\ ;\ C\,H^3\ ;\ S^2O^3 \\ H\ ;\ C\,H^3\ ;\ S^2O^3 \end{matrix}\right\}$ Potassa methyla sulphenite cum hydra methyla sulphenite.
72. $H\ ;\ C^2H^5\ ;\ S^2O^3$ Hydra ethyla sulphenite.
73. $C^2H^5\ ;\ C^2H^5\ ;\ S^2O^3$ Ethyla ethyla sulphenite.
74. $K\ ;\ C^2H^5\ ;\ S^2O^3$ Potassa ethyla sulphenite.

75. Ag; C^2H^5 ; S^2O^2 Argenta ethyla sulphenite.
76. Ba; C^2H^5 ; S^2O^3 Baryta ethyla sulphenite.
77. H; C^5H^{11}; S^2O^3 Hydra amyla sulphenite.
78. Ba; C^5H^{11}; S^2O^3 Baryta amyla sulphenite.

Group B. *Sulphites of the Radicals* nCH^2—H^7 and nCH^2—H^{13}.

79. H; C^6H^5 ; S^2O^3 Hydra phenyla sulphenite.
80. Cuc; C^6H^5 ; S^2O^3 Cupric phenyla sulphenite.
81. H; C^7H^7 ; S^2O^3 Hydra toluenyla sulphenite.
82. Ba; C^7H^7 ; S^2O^3 Baryta toluenyla sulphenite.
83. Ba; C^8H^9 ; S^2O^3 Baryta xylenyla sulphenite.
84. H; C^9H^{11}; S^2O^3 Hydra cumenyla sulphenite.
85. H; $C^{10}H^7$; S^2O^3 Hydra naphtyla sulphenite.
86. K; $C^{10}H^7$; S^2O^3 Potassa naphtyla sulphenite.
87. Ag; $C^{10}H^7$; S^2O^3 Argenta naphtyla sulphenite.
88. H; $C^{10}H^{13}$; S^2O^3 Hydra thymyla sulphenite.
89. Ba; $C^{10}H^{13}$; S^2O^3 Baryta thymyla sulphenite.

Group C. *Sulphites containing Chloric Vice-radicals.*

90. H; $C\ H^2Cl$; S^2O^3 Hydra chloric-methyla sulphenite.
91. H; $C\ H\ Cl^2$; S^2O^3 Hydra chlorenic-methyla sulphenite.
92. H; $C\ \ Cl^3$; S^2O^3 Hydra chlorinic-methyla sulphenite.
93. K; $C\ H^2Cl$; S^2O^3 Potassa chloric-methyla sulphenite.
94. Ag; $C\ H\ Cl^2$; S^2O^3 Argenta chlorenic-methyla sulphenite.
95. Ba; $C\ \ Cl^3$, S^2O^3 Baryta chlorinic-methyla sulphenite.
96. H; $C^{10}H^4Cl^3$; S^2O^3 Hydra chlorinic-naphtyla sulphenite.
97. H; $C^{10}H^5Br^2$; S^2O^3 Hydra bromenic-naphtyla sulphenite.

Group D. *Amidogen Sulphites.*

98. $\left\{\begin{matrix} ZH^2,SO \\ H\ ,SO^2 \end{matrix}\right\}$ Amida sulphate cum hydra sulphete.

99. $\left\{\begin{matrix} ZH^2,SO \\ CH^3,SO^2 \end{matrix}\right\}$ Amida sulphate cum methyla sulphete.

100. $\left\{\begin{matrix} ZH,C^6H^5;\ SO \\ H\ ;\ SO^2 \end{matrix}\right\}$ Phenylac sulphate cum hydra sulphete.

101. $\left\{\begin{matrix} ZH,C^6H^5;\ SO \\ Ba;\ SO^2 \end{matrix}\right\}$ Phenylac sulphate cum baryta sulphete.

102. $\left\{\begin{matrix} ZH,C^6H^5;\ SO \\ Ag;\ SO^2 \end{matrix}\right\}$ Phenylac sulphate cum argenta sulphete.

103. $\left\{\begin{matrix} ZH,C^7H^7;\ SO \\ ZH^4;\ SO^2 \end{matrix}\right\}$ Toluenylac sulphate cum ammona sulphete.

104. $\left\{\begin{matrix} ZH,C^7H^7;\ SO \\ K\ ;\ SO^2 \end{matrix}\right\}$ Toluenylac sulphate cum potassa sulphete.

105. $\left\{\begin{array}{r} ZH,C^{10}H^7 ;\ SO \\ H ;\ SO^2 \end{array}\right\}$ Naphtylac sulphate cum hydra sulphete.

METHYLODITHIONATES.

106. $Zn ; CH^3 ; (SO)^2$ Zinca methyla bisulphate.
107. $Ba ; CH^3 ; (SO)^2$ Baryta methyla bisulphate.
108. $Mg ; CH^3 ; (SO)^2$ Magna methyla bisulphate.
109. $Ca ; CH^3 ; (SO)^2$ Calca methyla bisulphate.

$$110.\ \left\{\begin{array}{l} H ; CH^3 ; (SO)^2 \quad \text{Hydra methyla bisulphate.} \\ = \left\{\begin{array}{r} CH^3,SO \\ H,SO \end{array}\right\} \text{Methyla sulphate cum hydra sulphate.} \end{array}\right.$$

ETHYLOTRITHIONATES.

111. $Zn ; C^2H^5 ; (SO)^3$ Zinca ethyla trisulphate.
112. $Ba ; C^2H^5 ; (SO)^3$ Baryta ethyla trisulphate.
113. $Ag ; C^2H^5 ; (SO)^3$ Argenta ethyla trisulphate.
114. $Cuc ; C^2H^5 ; (SO)^3$ Cupric ethyla trisulphate.
115. $Na ; C^2H^5 ; (SO)^3$ Natra ethyla trisulphate.
116. $C^2H^5 ; C^2H^5 ; (SO)^3$ Ethyla ethyla trisulphate.

$$117.\ \left\{\begin{array}{l} H ; C^2H^5 ; (SO)^3 \quad \text{Hydra ethyla trisulphate.} \\ = \left\{\begin{array}{r} C^2H^5,SO \\ H,S^2O^2 \end{array}\right\} \text{Ethyla sulphate cum hydra sulphenete.} \end{array}\right.$$

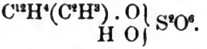
INVESTIGATION OF BISULPHATES OF BASIC RADICALS.

According to many chemists, the salts of this section, Groups A and B, Nos. 1 to 15, are conjugated sulphates, a class of salts in which the organic radicals are supposed to be combined with the sulphur and oxygen into monobasic conjugated acids. I have examined that theory in the Article which commences at page 399, and shown that it is not tenable, and that these salts ought to be described, as I have described them in this Table, as double sulphates.

Each salt in these two groups has four atoms of oxygen. In Group A, the organic radicals are all such as belong to the vinyl basic series. In Group B, they are such as belong to other series, but none of them have assumed the extra atom of oxygen which distinguishes certain acid radicals when they act as basic radicals.

Usual Names of these Bisulphates of Basic Radicals.—GROUP A, 1]. Sulphomethylic acid. The atom of basic hydrogen is replaceable by any other basic radical. 2]. Ethylosulphuric acid, or sulphovinic acid. The basic hydrogen, H^1, is replaceable by any other basic radical, and produces a great variety of double sulphates. 3]. An example of a normal sulphovinate, which is commonly said to be *monobasic*. 4]. A *biacid* sulphovinate. 5]. A *bibasic* sulphovinate. In this case one of the four sulphates contained in the salt has O^2, in consequence of the presence of two extra basic radicals, the analytical formula being $Pb,SO^3 + Pb,PbO$. Salts equivalent to No. 3, are produced by exchanging Pb for ZH^4, Na, K, Ba, L, Sr, Ca, Mg, Mn, Zn, &c. 6]. The barytic salt of trityl-sulphuric acid = $C^6H^7BaS^2O^8$, *Gerhardt.* 7]. Sulphobutylate of potash. 8]. Sulphamylic acid. 9]. Octylsulphuric acid. 10]. Cetyl-sulphuric acid. All these acids exchange H^1 for any other basic radical.

Group B.—11]. Sulpho-phenic acid. The H^1 is replaceable by a basic radical. 12] and 13] seem to me to be salts of precisely the same character as No. 11, the hydrogen in that salt being replaced by CH^3 to produce 12, and by CH^2Ba, to produce 13. Gerhardt, however, considers No. 12 to be a "conjugated acid." He calls it Methyl-sulphophenic acid, and gives it this formula—



$$\left.\begin{array}{r}C^{12}H^4(C^2H^3)\,.\,O\\ H\ O\end{array}\right\}S^2O^6.$$

The single atom of hydrogen represented in this formula he represents to be replaceable by barium, and so accounts for the production of the salt No. 13. In this theory, Gerhardt assumes that the radical methyl replaces one atom of hydrogen in the radical phenyl. Most of the modern French chemists, following Gerhardt, frequently resort to this practice of representing the hydrogen of hydro-carbons as replaceable by other complete hydro-carbons, atom for atom. To me, this practice appears to be highly pernicious, and one that, if carried out, would destroy the power of identifying radicals. But it is as unnecessary as it is dangerous. In the present instance, it is done merely to accommodate the formula to the barytic radical in No. 13, but surely it is better to adopt the theory of "*metallic vice-radicals*," page 137, which cannot possibly produce the muddle that must necessarily ensue from admitting the notion that hydro-carbons can replace hydrogen in other hydrocarbons, and produce compound intermediate hydrocarbons. According to Gerhardt, the organic radical which is present in methyl-sulphophenic acid is a hydro-carbon = C^7H^7. This agrees in composition with toluenyl, or with the radical which is commonly assumed to be present in anisole, and in fact Gerhardt calls the acid, not only methyl-sulphophenic acid, but also sulphanisolic acid. The question naturally arises, what radical is actually present in the salt? Is it anisol, or toluenyl, or methyl *plus* phenyl, or any other combination of radicals which can together amount to C^7H^7? Why, without the slightest necessity, should we adopt a practice which evidently opens a door to such interminable confusion?

14]. Thymylsulphuric acid, or sulphothymic acid. 15]. The baryta salt of that "conjugated acid."

INVESTIGATION OF BISULPHATES OF ACID RADICALS.

Examples Nos. 16 to 42.

These salts are either double sulphates or triple salts. The hydrocarbon that is present in each of them, is an acid radical. Consequently, there is in each salt an addition to that quantity of oxygen, which is required to complete a normal sulphate, when its hydrocarbon is basic.

I will introduce the explanation of these salts by an account of some recent researches by MM. Buckton and Hofmann (*Proceedings of the Royal Society*, vii. 544, and viii. 158; also *Quarterly Journal of the Chemical Society*. 1856, ix. 241).

When acetamide is acted upon by fuming oil of vitriol, the results are such as may be represented as follows:—

$$\left.\begin{array}{l} ZH^2,C^2H^3O \\ ZH^2,C^2H^3O \\ (H\,,SO^2)^8 \end{array}\right\} = \left\{\begin{array}{ll} \left\{\begin{array}{l} ZH^4,S\,O^2 \\ ZH^4,S\,O^2 \end{array}\right\} & = a. \\ \left\{\begin{array}{r} H\,,C^2H^3O^2 \\ H\,,S\,O^2 \\ H\,,S\,O^2 \end{array}\right\} & = b. \\ \left\{\begin{array}{r} CH^3,S^2O^3 \\ H\,,S^2O^3 \end{array}\right\} & = c. \\ \qquad\quad ,C\,O^2 & = d. \end{array}\right.$$

Two atoms of acetamide and eight atoms of sulphuric acid produce in the main (for the products vary according to the manner of conducting the process) as follows:

- *a.* Two atoms of sulphate of ammonia. These carry off the nitrogen.
- *b.* A combination of one atom of hydrated acetic acid with two atoms of hydrated sulphuric acid = No. 16].
- *c.* A double or acid hyposulphate of methyl = No. 44.
- *d.* An atom of carbonic acid, *set free*.

The methods of separating the three salts, *a*, *b*, *c*, are described by MM. Buckton and Hofmann, but need not be repeated here. By operating upon other amids in this manner, similar results were obtained. Each decomposition affording a salt belonging to the Bisulphates of Acid Radicals in company with another salt belonging to the Double Hyposulphates with basic radicals. The production of the salt *c* depends, of course, upon the reduction of the acid radical to the corresponding basic radical by the expulsion of C^1. That is effected by using a sufficient excess of acid, and a suitable high temperature: CO^2 then flies off, and the nascent basic radical combines with the sulphuric acid.

GROUP A. *Bisulphates of Radicals of the Vinyl Series*, Nos. 16 to 25.

16]. $H,C^2H^3O^2 + 2(H,SO^2)$

This triple acid can be obtained in the state of dehydrated crystals that have the composition represented by the formula. The usual crystals contain ½ aq. in addition to what is represented in the formula. This compound is the sulphacetic acid of organic chemists: Melsen's formula for it is $C^4(H^2SO^2)O^3,SO^3 2HO + 2Aq$. By an abstraction of HHO, the compound No. 16 is reduced to No. 17.

17]. $C^2H^3,SO^3 + H,SO^2$.

Miller's formula for sulphacetic acid is $2HO,C^4H^2S^2O^8$, and Hofmann's formula is $C^4H^4S^2O^{10}$, both of which represent it as a bibasic conjugated acid. I have not, however, met with any analysis of an acid of this composition, although the form agrees with that of many of the normal salts.

18]. $C^2H^2Ba,SO^3 + Ba,SO^2$.

The sulphacetate of barytes. Hofmann's formula = $C^4(H^2Ba^2)S^2O^{10}$. Gmelin's formula = $C^4H^2Ba^2O^4,2SO^3$. Miller's formula = $2BaO, C^4H^2S^2O^8$. These formulæ all intimate the presence of a bibasic conjugated acid.

Now, let us examine this point, whether the evidence is sufficient to prove the existence in these salts of an acid radical which is conjugated of acetyl and sulphur.

Suppose the acid No. 16 to be deprived of an atom of HHO. The residues would be C^2H^3,H,S,S,O^5, and the question to be solved is, in what order do these atoms combine with one another to form a compound salt?

$$\text{Is it so: } \begin{array}{ll} H,C^2H^2 & SO^3 \\ H, & SO^2 \end{array}; \text{ or so: } \begin{array}{l} C^2H^3,SO^3 \\ H\ ,SO^2 \end{array}?$$

According to the first supposition, we have a double salt, containing a sulphic vice-radical, such as I have described at page 136, which radical, in this case, is sulphacetyl = C^2H^2S, where H^1 is replaced by S^1, subject to the addition of O^1 to the oxygen of every salt into which the conjugated radical enters. This supposition, as I have shown at page 137, agrees with the composition of the salts; and according to it, the salt, No. 18], cited above, would be represented by the formula:

$$Ba,C^2H^2SO^3 + Ba,SO^2.$$

But this supposition leaves out of consideration the important fact, to which I have adverted in the beginning of this Section, namely, that an acid radical can act the part of a basic radical, provided an addition of oxygen is made to its salts. On that principle the formula No. 17 is founded; for in the salt which that formula represents, we have a sulphate with acetyl for its basic radical, and consequently with O^3 as its quantum of oxygen.

The objection that applies to this formula is, that sulphacetic acid (like all the acids of this category) is *bibasic*, while the double acid, represented by formula 17, contains but one atom of basic hydrogen. To meet that objection, another fact comes into play, namely, the fact that hydrocarbons, when acting as basic radicals, can exchange an atom of hydrogen for a metal, and produce a metallic vice-radical. I have proved this to be the case in so many instances, that I do not hesitate to cite it as a fact that is incontestable.

These considerations drive the argument into a corner. We have to choose between these two probabilities: does acetyl in the sulphacetates exist as an acid radical in combination with sulphur = C^2H^2S, or as a basic radical in combination with a metal = C^2H^2M? I am decidedly in favour of the latter opinion, and I do not now, as I once did, consider the existing evidence to be in favour of the occurrence of sulphic radicals. When I wrote the Article on sulphic radicals at page 136, and those on the sulphur salts of indigo between pages 269 and 274, I was favourable to the theory of sulphic radicals; but the facts developed during the investigation into the polyatomic alcohols respecting the power of acid radicals to act as basic radicals under certain conditions of suroxidation, together with the ever-increasing proof of the existence of basic hydrocarbons containing metals by substitution for hydrogen, have completely changed my opinion; and I now consider that the evidence which tends to prove the existence of sulphic radicals is outweighed by that which tends to prove the contrary, and consequently that we have no right to assume that such things as conjugated sulpho-acids exist. I shall show that all the salts that are collected under this head are subject to an interpretation which is independent of the theory of conjugated acids.

I conclude, therefore, that the salt No. 18 is properly represented as a double sulphate, one of the salts being in its normal state, and the other containing barytic-acetyl, and, therefore, an additional atom of oxygen.

$$19a]. = \begin{array}{l} C^2H^3\ ,SO^3 \\ HBa^2,SO^3 \end{array} \text{ or } \begin{array}{l} H\ ,C^2H^3O^2 \\ (Ba,SO^2)^2. \end{array} = 19].$$

The barytic salt No. 19 is procurable in crystals, which may be explained by either of these two formulæ. According to the first formula, we have a sulphate of acetyl combined with a terbasic sulphate. Both salts contain O^3, the first because of the presence of an acid radical, the second because of the presence of three basic radicals. According to the second form we have hydrated acetic acid, in combination with two atoms of sulphate of barytes. This form agrees with the hydrated acid No. 16, and is, I think, the most probable. When this salt is heated, HHO goes away, and a new arrangement of atoms occurs, which produces the salt No. 18.

20]. $C^2H^2Ag,SO^3 + Ag,SO^2$,

the silver salt of the same acid. Numerous other salts might be quoted, but none which afford additional evidence on the point now discussed. In matters of this sort, cumulative concurrent evidence adds to the *probability* of the truth of a theory, but does not make it *certain*.

21]. $C^3H^4Ba\ ,SO^3 + Ba\ ,SO^2$.
22]. $C^3H^5\ ,SO^3 + H\ ,SO^2$.
23]. $ZH^3,C^3H^5,SO^3 + ZH^4,SO^2$.
24]. $C^4H^6Ba\ ,SO^3 + Ba\ ,SO^2$.
25]. $C^4H^7\ ,SO^3 + H\ ,SO^2$.

Usual Names:—**21**]. Sulphopropionate of barium = $C^6(H^4Ba^2)S^2O^{10}$, *Buckton and Hofmann.* **22**]. Sulphopropionic acid. 23]. Sulphopropionate of ammonium: (the relation of this salt to the acid No. **22**, plus two atoms of ammonia = $ZH^2H + ZH^2H$, is seen at a glance). **24**]. Sulphobutyrate of barium = $C^8(H^6Ba^2)S^2O^{10}$, *Buckton and Hofmann.* 25]. Sulphobutyric acid.

These salts differ from the sulphacetates only by the substitution of propionyl = C^3H^5, and butyryl = C^4H^7, for acetyl = C^2H^3. The theory which applies to sulphacetic acid applies to every acid of this description. It is, I think, wrong to call them "acids." They are simply double sulphates modified by the quantity of oxygen which is governed by the organic radicals and metallic vice-radicals.

Group B. *Bisulphates containing Benzyl*, Nos. 26 to 34.

No. 26 in this series is sulphobenzoic acid, and the other salts, from 27 to 34, are sulphobenzoates. The theory of these salts is precisely similar to that of the preceding group, and it is useless to cite them individually for discussion. One or two points may be noticed. No. **27**, the monobarytic salt, is a form that has not yet been found among the salts of the preceding group. The salts Nos. 31 to 34 have been recently described by Limpricht, who is of opinion that the acid of No. 31 contains not only sulphur and benzyl but ethyl. He calls it ethyl-sulphobenzoic acid. The ammonia salt, No. 32, he calls ethyl-sulphobenzoate of ammonia, and the formula which he gives for it is $\left.\begin{matrix} C^{14}H^4\ S^2O^6 \\ (C^4\ H^5)NH^4 \end{matrix}\right\} O^4$. My interpretation of these salts is entirely different. I consider No. 31 to be a double sulphate, but having O^1 extra, because of the presence of benzyl in the condition of its basic radical: the ethyl, of course, demands no additional oxygen. When a metal acts upon this double salt, the odd atom of hydrogen in the ethyl is exchanged for it, and thus the salts 33 and 34 are produced. When ammonia acts upon No. 31 it simply converts the ethyl into ethylam, which, being a normal ammonam, demands no additional oxygen, as is seen in No. **32**.

Group C. Bisulphates containing Anisyl, Cinnamyl, and Spiryl.

Nos. 35 to 43.

The bisulphates that contain anisyl have been recently investigated by Zervas, under the guidance of Hofmann (*Proceedings of the Royal Society*, 1857, viii. 494; *Quarterly Journal Chemical Society*, 1857, x. 211). The compounds were prepared by the action of fuming sulphuric acid on anisic acid.

35]. $H,C^8H^7O^3 + 2(H\ ,SO^2)$.
36]. $H,C^8H^7O^3 + 2(Ba,SO^2)$.
37]. $H,C^8H^7O^3 + 2(Pb,SO^2)$.

These were crystallised salts, for which the discoverer gives the following formulæ:

for 35, $C^{16}\,H^8 \quad\quad S^2O^{12} + 2$ aq.
for 36, $C^{16}(H^6Ba^2)S^2O^{12} + 2$ aq.
for 37, $C^{16}(H^6Pb^2)S^2O^{12} + 2$ aq.

No. 35 is called sulphanisic acid, and the others are sulphanisates.

38]. $C^8H^7\quad ,SO^4 + H\ ,SO^2$.
39]. $C^8H^6Ba\,,SO^4 + Ba,SO^2$.
40]. $C^8H^6Pb,SO^4 + Pb,SO^2$.

No. 38 is produced by heating the crystals of 35 at 100° C. No. 39. by heating the crystals of 36 at 170° C. No. 40, by heating the crystals of 37 at 176° C.

Theory.—There is here no evidence of the formation of the "conjugated" sulphanisic acid. The first three salts are combinations of sulphates with hydrated anisic acid. The others differ from these in consequence of having each undergone an abstraction of HHO. The effect of this abstraction of HHO is, to throw the anisyl into the condition of a basic radical, and as this acid radical requires O^3 for its normal salts, on becoming basic, it carries with it O^2, and consequently raises the oxygen of the sulphate into which it enters from O^2 to O^4. In this respect only do the sulphanisates differ in principle from the sulphacetates and sulphobenzoates.

41]. $C^9H^7 \quad SO^3 + H,\ SO^2$.
42]. $C^9H^6Ag,SO^3 + Ag,SO^2$.

No. 41 is the sulphocinnamic acid, and 42 its silver salt. There are many other salts similar to No. 42. It is evident at a glance that these salts resemble those which contain benzyl, group B, and that they require no other theoretical explanation.

43]. $C^7H^5,SO^4 + H,SO^2$.

Hofmann quotes this formula (or rather he quotes $C^{14}H^6S^2O^{12}$) as that of another new conjugated acid, the sulpho-salicylic acid, recently discovered by Mr. Baldwin Duppa. No particulars are given respecting the salt. The correctness of this formula is doubtful. C^7H^5 represents spiryl, not salicyl, but spiryl could scarcely require O^4 in its sulphate.

INVESTIGATION OF DOUBLE HYPOSULPHATES.

A Hyposulphate contains two atoms of sulphur, three atoms of oxygen, and one positive radical (see page 172). There is no *à priori* argument against the possibility of the formation of double hyposulphates. I conclude thence, that the salts in the Table, from No. 44 to 59, are all double hyposulphates, and that they contain no conjugated acids of any description whatever. It may be urged in opposition to this opinion, that the properties and reactions of these salts are not in accordance with the properties and reactions of hyposulphates; but it does not appear to me that the properties and reactions of hyposulphates are, at present, known with such perfection that much reliance can be placed on arguments which depend solely upon that knowledge.

The process by which these salts are produced has been described in general terms at page 488.

All the basic radicals that are contained in the salts that form groups A, B, C, are truly basic, and therefore they bring no additioanl oxygen into the salts. In group D, we perceive the radical C^7H^7, the nature of which I do not understand, but which has evidently the power of an acid radical of the benzyl series, and consequently adds O^1 to its salts.

All the other particulars that are exhibited by the formulæ, from Nos. 44 to 59, have been so fully discussed, that the reader will immediately comprehend the meanings that these formulæ are intended to convey. But as the discovery of these salts is but recent, and as their discoverers are impressed with the conviction that they have discovered *five or six* NEW ACIDS, I will quote some of their names and formulæ. My impression is, that the salts are hyposulphates, and nothing else. If this impression is correct, I apprehend that little favour is due to mere names which imply the existence of conjectural conjugated acids. Not one such acid ought to be recognised as existent without conclusive evidence in its favour. The law of simplicity commands us to admit in chemistry of the existence of no greater variety of substances than nature actually produces: they are numerous enough in all conscience. Every new conjugated acid, and every new polyatomic base, which speculative chemists adopt inconsiderately and without necessity, is an injury to the exactness and an obstacle to the progress of true science.

Groups A and B. *Names and Formulæ given by Messrs. Buckton and Hofmann.*

44]. Disulphometholic acid = $C^2\ H^4S^4O^{12}$.
45]. Disulphometholate of barium = $C^2(H^2Ba^2)S^4O^{12}$.

46]. Disulphometholate of silver = $C^2(H^2Ag^2)S^4O^{12}$.
47]. Disulphometholate of Ammonium = $C^2[H^2(NH^4)^2]S^4O^{12}$.
48]. Disulphetholic acid = $C^4\ H^6S^4O^{12}$.
49]. Disulphetholate of barium = $C^4(H^4Ba^2)S^4O^{12}$.
50]. Disulphetholate of ammonium = $C^4[H^4(NH^4)^2]S^4O^{12}$.
51]. Disulphopropiolic acid = $C^6(H^8)S^4O^{12}$.
52]. Disulphopropiolate of barium = $C^6(H^6Ba^2)S^4O^{12}$.
53]. Disulphobenzolic acid = $C^{12}H^6S^4O^{12}$.
54]. Disulphobenzolate of barium = $C^{12}(H^4Ba^2)S^4O^{12}$.

Group C. *Names quoted by Gerhardt.*

55]. Disulphonaphtalic acid; thionaphtic acid; hyposulphonaphtic acid = $C^{20}H^8S^4O^{12} = C^{20}H^8 + 4(SO^3,HO) - 4HO$.
56. Disulphonaphtalate of barytes = $C^{20}H^6Ba^2S^4O^{12}$.

Group D. *Names of Zervas and Hofmann.*

57]. Disulphanisolate of barium = $C^{14}(H^6Ba^2)S^4O^{14} + 2$ aq. This salt is evidently a quadra-sulphate, the four basic radicals of which are Ba, Ba, C^7H^7, and H. The salts Nos. 58 and 59 were *inferred* to exist, rather than *proved* to exist, by these chemists.

Looking over these salts, there seems to be no evidence to favour the assumption of the existence of a series of conjugated sulpho-acids, but much to prove the accuracy of the formulæ which are given in the Table, and according to which these salts are all hyposulphates.

The radical marked C^7H^7 is derived from anisyl C^8H^7 by abstraction of C^1. Hofmann calls it *anisol*. Is it toluenyl = C^7H^7, or some other isomeric radical? It acts here as an acid radical, whereas toluenyl acts as a basic radical (see No. 81).

Group E. *Amidogen Hyposulphates.*

Usual Names.—60]. Disulphanilic acid = $C^{12}H^7NS^4O^{12}$, *Buckton and Hofmann*. 61]. Disulphanilate of barium = $C^{12}(H^5Ba^2)NS^4O^{12}$, *B. and H.* 62]. Disulphanilate of silver = $C^{12}(H^5Ag^2)NS^4O^{12}$, *B. and H.* 63]. Dithiobenzolic acid = $C^{12}H^8N^2S^4O^{12}$, *Hilkenkamp*. Phenyldisulphodiamic acid, *Hofmann*. 64]. The barium salt of that acid. The salts of this group have been described at page 240. There is a peculiarity in their composition which I do not understand. If HHO is added to the amidogen salt No. 60 we produce $\left.\begin{array}{r}ZH^3,C^6H^5\ ;\ S^2O^4\\ H\ ;\ S^2O^3\end{array}\right\}$. The upper member of this salt represents twice as much sulphur and oxygen as belongs to a sulphate in combination with only one basic radical.

If 2 (HHO) is added to the double amidogen salt No. 64 we produce $\left.\begin{array}{l}ZH^2,C^6H^5\ ;\ S^2O^4\\ ZH^2,Ba^2\ \ ;\ S^2O^4\end{array}\right\}$. This is a double salt, with a similar disproportion of acid radicals to basic radicals. Other examples occur,—see page 241,—in which amidogens seem to be equally competent with ammoniums to act as basic radicals in hyposulphates.

INVESTIGATION OF THE SULPHITES.

A sulphite contains two atoms of sulphur, three atoms of oxygen, and two positive radicals. See pages 171 and 237.

The salts described in the Table, from Nos. 65 to 97, are all formed in accordance with these particulars, and consequently are entitled to be called sulphites. The common practice of organic chemists is, however, to represent them as salts of conjugated acids, chiefly under the supposition, that the organic radical which is present in each salt is not present in the character of a basic radical, but is conjugated with the sulphur into a compound acid radical. The arguments by which that supposition is supported have been examined in the article which commences at page 399, in which I have shown that the evidence adduced, instead of proving the existence of conjugated acids, proves exactly the reverse. Referring the reader to those arguments and facts, I assume here, that all the compound radicals which appear in this Table are present in the salts in the condition of basic radicals, that the salts are sulphites, and that the theory of conjugated acids is totally inapplicable to every one of them.

Even the chloric- and bromic-vice-radicals, some of them containing two or three atoms of chlorine or of bromine, with no hydrogen, still act in these salts as basic radicals, and have no effect on the quantum of oxygen which is demanded by the sulphur for the formation of normal sulphites.

GROUP A. *Sulphites with Alcohol Radicals.* Nos. 65 to 78.

65]. $H; CH^3; S^2O^3 = CH^3,SO + H,SO^2$. The H being replaceable, this acid gives rise to the salts that are formulated in Nos. 66 to 71, and to many others. This acid has been called Sulphosomethylic acid. Hyposulphomethylic acid, *Gmelin*. Acide méthyl-sulfureux; acide methyl-dithionique, or sulfomethyl-sulfurique

$$= C^2H^4S^2O^6 = \left.\begin{matrix} C^2H^3,O \\ H\ \ O \end{matrix}\right\} S^2O^6, \textit{ Gerhardt.}$$

Acide sulfoformique, *Laurent*. Methylunterschwefelsäure, or Hydrated hyposulphate of methyl = C^2H^3,S^2O^5,HO, *Kolbe*. In applying the term hyposulphate to a salt of this formula, Kolbe seems to have considered only the relations of the sulphur and oxygen, and to have forgotten that with these proportions of S and O, the presence of two basic radicals makes a sulphite, while a hyposulphate requires only one basic radical. But probably Kolbe was guided in his opinion by the notion that in this case the hydrogen alone acted as the basic radical, and that the methyl

$= C^2H^3$ acted merely as a neutral, indifferent, powerless, hanger-on, like the basic radicals in his copulated oxalates, which I have described at page 408. However, the mistaking of sulphites for hyposulphates is not peculiar to Kolbe, but is a common practice among organic chemists.

66] to 71]. These are salts of the "acid" No. 65, and therefore demand no particular explanation. No. 71 is a double or acid salt. No. 69 is a salt one half of which is terbasic. In this example we have the proportions of S and O which are proper to a normal sulphate, but with twice the ordinary number of basic radicals.

72]. $H ; C^2H^5 ; S^2O^3 = C^2H^5,SO + H,SO^2$. This is commonly called the Ethylosulphurous acid. Nos. 73 to 76 are examples of its salts, of which many more might be quoted. No. 73 is also called the sulphite of ethyl, and affords an instance of an organic salt, which, for a wonder, organic chemists have omitted to convert into a conjugated acid.

77]. The hyposulphamylic acid. 78]. Its barium salt.

GROUP B. *Sulphites containing Radicals of the Series* $nCH^2 - H^7$, and $nCH^2 - H^{13}$.

79]. $H ; C^6H^5 ; S^2O^3 = C^6H^5,SO + H,SO^2$. All the salts of Group B have this constitution. The H, of course, is replaceable by a basic radical, and gives rise in each case to a series of salts.

Usual names. 79]. Funeschwefelsäure, *Gmelin.* Acide phényl-sulfureux or acide sulfobenzidic

$$= \left.\begin{matrix} C^{12}H^5S^2O^4.O \\ HO \end{matrix}\right\} \textit{Gerhardt.}$$

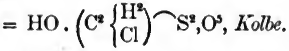
Hyposulphobenzidic acid, *Gregory.* Sulphobenzolic acid $= HO,C^{12}H^5S^2O^5$, *Miller.* 80]. The copper salt of the acid 79. 81]. Sulphotoluylic acid. Thiotoluic acid. Acide sulfobenzoénique. Toluolschwefelsäure. 82]. Its barium salt. 83]. The barium salt of xylenyl-sulphurous acid, or Sulpho-xyloic acid. 84]. Cumenyl-sulphurous acid. Sulphocumenic acid. 85]. Sulphonaphtalic acid. Naphtyl-sulphurous acid. Hyposulphonaphtalic acid. Naphtyl-dithionic acid. 86 and 87]. Salts of the acid No. 85. 88]. Thymyl-sulphurous acid, Sulphocymenic acid, or sulphocamphic acid, *Gerhardt.* 89]. Its barium salt.

GROUP C. *Sulphites containing Chloric Vice-Radicals.*

The salts Nos. 90, 91, 92, differ from the salt No. 65, only by the substitution of chloric-, chlorenic-, and chlorinic-methyl, in the place of normal methyl. The resulting salts retain the usual form and the usual quantity of oxygen. The salts Nos. 93, 94, and 95, differ to the same extent from the normal salts Nos. 70, 67, and 66. The salts Nos. 96 and 97, differ from the salt No. 85, only by the replacement of naphtyl by chlorinic- and bromenic-naphtyl.

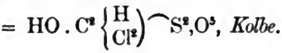
Nevertheless, these simple relations have been overlooked, and chemists have given to these salts a variety of very complex names and formulæ, depending upon equally complicated and diversified theories; for a full account of which I refer the reader to Gmelin's *Handbook of Chemistry*, vii., 295 to 303, and 351.

Usual names. 90]. Chloro-sulphosomethylic acid, *Gmelin.* Chlorelayl - Unterschwefelsäure, chlorelaylhyposulphuric acid, or chloromethylodithionic acid



$$= HO\,.\left(C^2\left\{\begin{matrix}H^2\\ Cl\end{matrix}\right.\right)\frown S^2,O^5,\ \textit{Kolbe.}$$

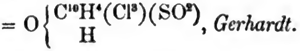
Acide sulfoformique chloré, *Laurent.* Acide métholique chlorosulfuré, *Gerhardt.* 93]. One of its salts. 91]. Bichlorosulphosomethylic acid, *Gmelin.* Chlorformyl - Unterschwefelsäure, Dichloromethylodithionic acid, or chloroformylohyposulphuric acid



$$= HO\,.\,C^2\left\{\begin{matrix}H\\ Cl^2\end{matrix}\right)\frown S^2,O^5,\ \textit{Kolbe.}$$

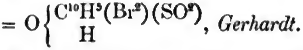
Acide sulfoformique bichloré, *Laurent.* Acide metholique bichlorosulfuré, *Gerhardt.* 94]. Its silver salt. 92]. Terchloro-sulphosomethylic acid, *Gmelin.* Terchlorinated Sulphosomethylic acid, *Gmelin.* Chlorkohlen-Unterschwefelsäure, chlorocarbohyposulphuric acid, or trichloromethylodithionic acid $= HO\,.\,(C^2Cl^3)\frown S^2,O^5$, *Kolbe.* Acide sulfoformique trichloré, *Laurent.* Acide metholique trichlorosulfuré, *Gerhardt.* 95]. Its barium salt. According to Kolbe, the chloric vice-radical which forms part of each salt, is copulated with the two atoms of sulphur into a single acid radical. That process apparently converts the salts from sulphites into hyposulphates. But there is no evidence that this copulation takes place; the salts can be described with simplicity as sulphites; and the existence of the copulated hyposulphates is highly improbable.

96]. Trichloro-sulphonaphtalic acid



$$= O\left\{\begin{matrix}C^{10}H^4(Cl^3)(SO^2)\\ H\end{matrix}\right.,\ \textit{Gerhardt.}$$

97]. Bibromo-sulphonaphtalic acid



$$= O\left\{\begin{matrix}C^{10}H^5(Br^2)(SO^2)\\ H\end{matrix}\right.,\ \textit{Gerhardt.}$$

In these last two formulæ, chlorinic-naphtyl, or bromenic-naphtyl, in company with two atoms of sulphur and two atoms of oxygen, are made to be collectively equal to H^1. This arbitrary ascription of the model of water to compounds which are evidently double salts is not to be justified. The manufacture of conjugated acids in this easy way is a farce.

GROUP D. *Amidogen Sulphites.* Nos. 98 to 105.

The salts of this group have all been described in former sections, and it is consequently needless to dwell upon them again in detail. The amidogen sulphites are all to be considered as double sulphates minus HHO; for if we suppose an addition of HHO to be made to each of the salts in this Table, they immediately become converted into normal bisulphates or double sulphates. Thus:

$$98].\quad \begin{matrix} ZH^2,SO + HHO \\ H\ ,SO^2 \end{matrix} = \begin{cases} ZH^4,SO^2 \\ H\ ,SO^2 \end{cases}$$

$$105].\quad \begin{matrix} ZH,C^{10}H^7 ; SO + HHO \\ H\ ; SO^2 \end{matrix} = \begin{cases} ZH^3,C^{10}H^7 ; SO^2 \\ H\ ; SO^2 \end{cases}$$

Usual Names. 98]. See 312, page 233. 99]. Sulphomethylane; see 320, page 237. 100]. Sulphanilic acid; see 321, page 237, and 28, page 285. 101] and 102]. Salts of sulphanilic acid; see Nos. 324 and 323, page 237, and No. 29, page 285. 103] and 104]. Thiotolnates; see Nos. 331 and 332, page 240. 105]. Thionaphtamic acid; see No. 329, page 240.

INVESTIGATION OF THE METHYLODITHIONATES. The Methylodithionates have recently been described by Dr. J. T. Hobson (*Quarterly Journal of the Chemical Society*, 1857, x. 248,) as part of a "New Series of Organo-Thionic Acids." The name *methylodithionates* was not well chosen, because Gerhardt has already applied it to another series of salts, the acid sulphites of methyl, forming Group A of this Table; see note to No. 65. Dr. Hobson's methylodithionates were prepared by acting upon zinc-methyl with sulphurous acid. The formulæ which he gives, as representing the results of the analyses, are as follow:—

106]. Methylodithionate of Zinc $ZnO,S^2 \begin{Bmatrix} C^2H^3 \\ O^3 \end{Bmatrix}$

107]. Methylodithionate of Baryta $BaO,S^2 . \begin{Bmatrix} C^2H^3 \\ O^3 \end{Bmatrix}$

108]. Methylodithionate of Magnesia $MgO,S^2 \begin{Bmatrix} C^2H^3 \\ O^3 \end{Bmatrix}$

109]. Methylodithionate of Lime $CaO,S^2 \begin{Bmatrix} C^2H^3 \\ O^3 \end{Bmatrix}$

110]. The "acid" was found to be very unstable, and could not be procured in a condition fit for analysis. Its composition was calculated from that of the salts.

It appears to me, that this "methylodithionic acid" has no existence, and that these salts are hyposulphites, constituted in accordance with the formula which I have explained in the article commencing at page 160. The salt No. 106, for example, is

$CH^3,SO + Zn,SO$ Methyla sulphate cum zinca sulphate.

The other salts are constituted in a similar manner.

INVESTIGATION OF THE ETHYLOTRITHIONATES.

The Ethylotrithionates have been described by Dr. J. T. Hobson (*Quarterly Journal of the Chemical Society*, 1857, x. 55). They were produced by acting on zinc-ethyl with sulphurous acid. They are, like the methylodithionates, stated by Dr. Hobson to be part of a "New Series of Organo-Thionic Acids." The formulæ which he assigns to the salts are as follow (I omit water of crystallisation):—

111].	$ZnO\ ,S^3(C^4H^5)O^5$.	Ethylotrithionate of zinc.
112].	$BaO\ ,S^3(C^4H^5)O^5$.	Ethylotrithionate of baryta.
113].	$AgO\ ,S^3(C^4H^5)O^5$.	Ethylotrithionate of silver.
114].	$CuO\ ,S^3(C^4H^5)O^5$.	Ethylotrithionate of copper.
115].	$NaO\ ,S^3(C^4H^5)O^5$.	Ethylotrithionate of soda.
116].	$C^4H^5O,S^3(C^4H^5)O^5$.	Ethylotrithionate of oxide of ethyl.
117].	$HO,\ S^3(C^4H^5)O^5$.	Ethylotrithionic acid.

Dr. Hobson's theory is expressed thus: "The compound [No. 111] is the zinc salt of a new acid, formed by the substitution of one equivalent of oxygen in three equivalents of sulphurous acid by ethyl." This supposition is by no means sufficient to prove the existence of a conjugated acid. I do not believe that the ethyl goes thus into the acid radical. That assumption is negatived by the evidence given in the section which commences at page 399. I therefore consider ethyl as sustaining in these salts its normal character of a basic radical.

If we could consider zinc-ethyl to be a radical, (and its atomic measure of one volume might tend to lead us to that opinion,) then, these salts might at once be described as *trithionates*, using that term in the sense in which it is used in the Article at page 168. Thus, the salt called ethylotrithionate of zinc, No. 111, would be rendered ZnC^4H^5,S^3O^3.

But I am of opinion, that zinc-ethyl is not a radical, but a salt. The grounds of that opinion are stated at page 106. Hence, these salts cannot be trithionates. If we throw the synoptical formula No. 111 into an analytical formula, we produce:

$$\begin{array}{l} C^2H^5,SO \\ \quad Zn,SO,SO \end{array}$$

and comparing this formula with that of the different polythionic salts, which I have described in the Article commencing at page 156, I conclude that the ethylotrithionates are compounds of a *sulphate* = C^2H^5,SO (page 159) with a *sulphenete* = Zn,SO,SO (page 170). The circumstance that salts of this constitution are at present nearly unknown, is no obstacle to their acknowledgment when they are made known. Hitherto, in fact, they have not been looked for, and, as I have shown in the investigation into the constitution of the polythionates, many varieties of oxysulphur salts have been disregarded, because the minds of chemists were preoccupied by erroneous notions respecting their constitution. The sulphenetes are salts in which sulphurous acid = SO, is combined with a salt of the form MSO, just as the hyposulphates consist of SO combined with a salt of the form MSO^2. In such a supposition there is nothing improbable, and by accepting it we are provided with satisfactory formulæ for the salts now in question, and freed from the necessity of admitting without proof the existence of a conjugated acid.

I have gone somewhat into detail respecting the "Conjugated Sulpho-acids," because chemists are in the common practice of taking for granted that such compounds actually exist; for which reason I have thought it proper to show them, that we have no evidence to prove the existence of even a single acid of this description. Our Books, indeed, are crammed with their Names, but Nature objects to make the Things.

The Silicates.

Much controversy has taken place respecting the composition of silica and the silicates. Different chemists have ascribed to silica the following formulæ:

SiO^3,	SiO^2,	and	SiO.
Berzelius.	Gmelin.		Thomson.

In the year 1834 I suggested that silica ought to be denoted by Si^2O, and the neutral silicates by MSiO. These formulæ seem now, after twenty-four years of research and reflection, to be more probable exponents of the truth than any of the other formulæ.

The most recent "researches on silica" have been made by Colonel Philip Yorke (*Proceedings of the Royal Society*, April 1857, viii. 440). His method of operating was that of "determining the quantity of carbonic acid which is displaced from excess of an alkaline carbonate in fusion, by a given weight of silica." The results were as follows:—When carbonate of potash was used, the experiments indicated the formula SiO^2. When carbonate of soda was used, the formula indicated was SiO^3. When carbonate of lithia was used, the formula became SiO. These experimental results gave, therefore, no satisfactory theoretical result. The process led to nothing, because silicates of fixed alkalies, whatever their composition, fuse with indefinite quantities of silica, and produce a variety of silicates, which differ in composition, according to the proportions of the ingredients in the mixtures, the degree of heat employed, and the time of its duration. To this principle it is that glasses and glazes owe their variety.

Colonel Yorke's conclusions were as follow. "After guarding himself from drawing any decided inference from the experiments recorded, the Author concludes by observing that at present he can see no alternative but to admit of more than one equivalent for silicic acid (that is to say, of more than one acid), the value of which is determined by circumstances, such as the presence of water and the nature of the base to which it is presented. The existence of such different silicic acids has been already suggested by chemists at different periods, particularly by Ebelmen and Laurent, and lately by M. Fremy."

I think we may come to a more satisfactory result respecting the atomic weight of silicon, if we examine the constitution of its gaseous compounds, and proceed, as I have done in the investigation of the compound radicals, from gases to solids, with the single view to make out, if we can, how much of the element which is under investigation is *the chemical equivalent of a single volume of hydrogen.* That quantity of the element must be accepted as its *atom.* Silicon must submit, like other elements, to this rule. Its atom, or Radical, is that quantity which replaces a volume of hydrogen.

In the Table of Gases, printed between pages 50 and 63, we have the following examples of gases that contain silicon:—

		Atomic measure.
Silicate of amyl, or amyla silate	C^5H^{11},SiO	½ volume.
Silicate of ethyl, or ethyla silate	C^4H^5,SiO	½ volume.
Chloride of silicon, or sila chlora	Si,Cl	½ volume.
Fluoride of silicon, or sila fluora	Si,F	½ volume.
Chlorosulphide of silicon, or sila sulpha bis sila chlora	$\left\{\begin{matrix} Si,S \\ (Si,Cl)^2 \end{matrix}\right\}$	1½ volume.

If we suppose the radical Si which appears in these formulæ to be, in all the examples, replaced by H, we should have the following series of well-known salts:

C^5H^{11},HO = amylic alcohol.
C^4H^5,HO = common alcohol.
H,Cl = hydrochloric acid.
H,F = hydrofluoric acid.
$2(HCl) + HS$ = a mixture of two atoms of hydrochloric acid with one atom of hydrosulphuric acid.

Here then is evidence clear and convincing, as far as it goes, that the quantity of silicon, which is the equivalent of H^1, is that which is marked in the Table by Si^1. An examination of the constitution and specific gravities of the respective gases fully explains the *weight* of this radical.

The composition of Silicate of Amyl = Amyla silate, is:

$$\begin{array}{lll} \text{Amyl} & = C^5H^{11} & = 71 \\ \text{Silicon} & = \text{Si} & = 7{\cdot}5 \\ \text{Oxygen} & = \text{O} & = 16 \\ \hline & & 94{\cdot}5 \end{array}$$

If this is doubled, it becomes 189, which represents its theoretical specific gravity, whereas Ebelmen's experiments showed it to be 169·3; which, though not a very accurate number, is sufficient to prove that the atomic measure of this gas is *half a volume*. Now, the corresponding gas, with H^1 instead of Si^1, amylic alcohol = C^5H^{11},HO measures *two volumes*. The cause of this differerence is explained at page 108, where I have shown that H^1, when it forms part of a salt, measures 1 volume, and does not alter the measure of the radical with which it combines to produce that salt, whereas the measure of silicon in a salt is 0 volume, while it diminishes the measure of the radical with which it combines to form that salt from 1 volume to half a volume. Hence it is, that all the siliceous gases measure half a volume for each atom of silicon which they contain.

This explanation applies to all the five gases which are quoted above. The chloride of silicon, or sila chlora = SiCl, has the following composition:—

$$\begin{array}{lll} \text{Silicon} & = \text{Si} = & 7{\cdot}5 \\ \text{Chlorine} & = \text{Cl} = & 35{\cdot}5 \\ \hline & & 43{\cdot}0 \end{array}$$

The theoretical specific gravity is 86, while Pierre found it experimentally to be 85·94. In the same way, the atomic weight of the silicate of ethyl, or ethyla silate = C^2H^5,SiO is shown in the Table, at page 58, to be 52·5; its theoretical specific gravity to be 105; and its experimental specific gravity, as determined by Ebelman, to be 105·92. The fluoride of silicon, or sila fluora = SiF, has an atomic weight of 26·5, and a theoretical specific gravity of 53, which Dumas found experimentally to be 52·09. Finally, the triple salt, the chlorosulphide of silicon = 2SiCl + SiS has the atomic weight of 109·5, which corresponds to the theoretical specific gravity of 73, its measure being 1½ volume, and this specific gravity is corroborated by the experimental weighings of Pierre, which gave 73·51.

These facts afford strong evidence in favour of the statement, that the atomic weight of silicon is 7·5. I adopt that conclusion as true, and I proceed to show how exactly it accords, not only with the composition of the siliceous gases and the chief artificial salts, but with the infinite variety of complex mineral silicates.

The composition of anhydrous silica, on this theory, is as follows:

		Per Cent.	By Expt.
Silicon, 2 atoms	= 7·5 + 2 = 15	= 48·39	48·275
Oxygen, 1 atom	= 16 + 1 = 16	= 51·61	51·725
	= Si,SiO = Sila silate.		

The *Chloride of Silicon* is decomposed by water, and produces hydrochloric acid and hydrated silica; thus:

$$\mathrm{SiCl + H,HO = H,SiO + HCl.}$$

This hydrated silica H,SiO is the model of the neutral silicates. The basic radical H is replaceable by any other basic radical. There are other varieties of hydrated silicic acid besides this normal hydrate. Doveri has shown that when it is air-dried at 60° F., its composition is:

$$\mathrm{H^2,Si^4O^3 = 2(H,SiO) + Si,SiO;}$$

and that when it is dried at 212° F., it becomes:

$$\mathrm{H^2,Si^8O^5 = 2(H,SiO) + 3(Si,SiO).}$$

We have consequently three, probably more, forms of hydrated silicic acid;—

$$\mathrm{H,SiO,} \qquad \mathrm{H^2,Si^4O^3,} \qquad \mathrm{H^2,Si^8O^5,}$$

all of which forms agree with many kinds of salts, both natural and factitious. Thus, there are three precisely similar varieties of silicate of ethyl, which are described in the following page.

Fluoride of Silicon = SiF = Sila fluora. When this gas acts upon water, one-third of the silicon separates as hydrated silica, and the solution contains hydrofluosilicic acid:

$$\left.\begin{array}{r}\mathrm{SiF + SiF + SiF}\\ \mathrm{+ HHO}\end{array}\right\} = \left\{\begin{array}{l}\mathrm{H,SiO}\\ \mathrm{HF + 2(SiF).}\end{array}\right.$$

This product HF + 2(SiF) = $\mathrm{HSi^2F^3}$ is the hydrofluosilicic acid. The $\mathrm{H^1}$ is replaceable by many other basic radicals, which replacement produces a variety of triple salts, called *Silico-fluorides.*

According to Berzelius's atomic weights, the preceding reaction is commonly represented as follows:

$$\mathrm{3SiF^3 + 3HO = 3HF.\ 2SiF^3 + SiO^3.}$$

In this equation O = 8, and Si signifies 3 times 7·5 of silicon, and this triple atom necessarily causes a triplication of all the other elements that are concerned in the reaction. But even with this triplication, the representation is not accurate, for $\mathrm{SiO^3}$ represents anhydrous silica, whereas the experiment produces hydrated silica, which demands 3HO in addition to what is scored in the above equation.

A comparison of these two equations shows that a great simplification of formulæ is produced by adopting the small atomic weight for silicon = 7·5. I may add a few examples to show this difference:

SILICO-FLUORIDES,	Usual Formulæ.	Proposed Formulæ.
Of Ammonium . . .	$3NH^4F . 2SiF^3$	$ZH^4Si^2F^3$
Aluminum . . .	$Al^2 F^3 . 2SiF^3$	$Alc\ Si^2F^3$
Barium	$3Ba\ F . 2SiF^3$	$Ba\ Si^2F^3$
Iron (ferrous) . .	$3Fe\ F . 2SiF^3$	$Fe\ Si^2F^3$
Iron (ferric) . . .	$Fe^2 F^3 . 2SiF^3$	$Fec\ Si^2F^3$
Copper (cuprous) .	$3Cu^2 F . 2SiF^3$	$Cu\ Si^2F^3$
Copper (cupric) . .	$3Cu\ F . 2SiF^3$	$Cuc\ Si^2F^5$
Mercurous . . .	$3Hg^2 F . 2SiF^3$	$Hg\ Si^2F^3$
Mercuric	$3Hg\ F . 2SiF^3$	$Hgc Si^2F^3$
Hydrogen	$3H\ F . 2SiF^3$	$H\ Si^2F^3$

The analytical form of the proposed formulæ is $H^rF + 2(SiF)$ where H^r is the replaceable atom. The names of such salts may be chosen to suit either the synoptical or the analytical formulæ; thus:

HSi^2F^3 = Hydra silen fluorine.
$HF + (SiF)^2$ = Hydra fluora bis sila fluora.
$FeSi^2F^3$ = Ferrous silen fluorine.
$FecF + (SiF)^2$ = Ferric fluora bis sila fluora.

Silicates of Ethyl. I have quoted the composition of one silicate of ethyl; but Ebelmen has described three varieties (*Gmelin's Handbook of Chemistry*, viii. 478-81).

	Gmelin's Formulæ.	Proposed Formulæ.
Disilicate of ethyl	= $2C^4H^5O,\ SiO^2$	$C^2H^5,Si\ O$
Monosilicate of ethyl	= $C^4H^5O,\ SiO^2$	$(C^2H^5)^2,Si^4O^3$
Bisilicate of ethyl	= $C^4H^5O,2SiO^2$	$(C^2H^5)^2,Si^8O^5$

These three varieties of silicate of ethyl correspond with the three descriptions of hydrated silicic acid referred to at page 503. I do not however admit these salts to be, as Colonel Yorke suggests, salts of *different acids*, but simply different kinds of multiple silicates:—

The Disilicate, being the normal salt:	The Monosilicate, being a triple salt:	The Bisilicate, being a fivefold salt.
C^2H^5,SiO	C^2H^5,SiO	C^2H^5,SiO
	C^2H^5,SiO	C^2H^5,SiO
	$Si\ ,SiO$	$Si\ ,SiO$
		$Si\ ,SiO$
		$Si\ ,SiO$
Ethyla silate.	Bis ethyla silate cum sila silate.	Bis ethyla silate tris sila silate.

For if we consider *a difference in the proportion* between the basic radicals and the silicon, or between the silicon and the oxygen, to be, in each case, the indication, or the proof, of the existence of a different silicic acid, we must prepare ourselves to accept of at least a HUNDRED *Silicic Acids*, for it would be easy to point out that number of varieties in the formulæ of well-known natural or artificial silicates.

Silicate of Amyl. I have described this salt by the formula C^5H^{11},SiO: Varrentrap describes it as $3C^{10}H^{11}O.SiO^3$; Gmelin as $2C^{10}H^{11}O,SiO^2 = C^{20}H^{22}SiO^4$; Gerhardt as $C^{40}H^{44}O^8Si^4 = 4(C^{10}H^{11}O,SiO)$. These high numbers result solely from the false estimate taken of the weight of the atom of silicon. Gmelin's $Si = 7 \cdot 5 + 2$; the others $= 7 \cdot 5 + 3$. One of these numbers causes duplication, and the other triplication of all the elements associated with the silicon.

I pass now to the consideration of MINERAL SILICATES, the composition of which I propose to explain in accordance with the notion that MSiO expresses a neutral or normal silicate, the M or basic radical in which is replaceable by hydrogen, or by any metal, either of the basylous order or basylic order, the difference between which I have explained at page 33.

The normal silicates thus formed, of all the different orders = H,SiO, R,SiO, and Rc,SiO, can combine with one another, and also with anhydrous silica = Si,SiO, and with salts formed on the model of water = H,HO, H,MO, and M,MO. Thence arise all the varieties of natural and factitious silicates—neutral, acid, and basic.

It follows from these premises, that *every silicate contains twice as many radicals as it contains atoms of oxygen.* Thus every simple silicate is MSiO, and every complex silicate is

$$R^x\,Rc^y\,Si^z\,O^1,$$

in which R signifies any basylous atoms, such as H, K, Na, Ba, Fe, Mn, &c., and Rc signifies any basylic atoms, such as Alc, Fec, Mnc, &c., while x, y, z, are collectively equal to *two* atoms, the quantity of oxygen being *one* atom.

There does not seem to me to be the slightest probability that, in the formation of the complex silicates, there is first produced a complex silicic acid, containing a multiple number of atoms of silicon, and that this *complex acid* then combines with an equally *complex base* containing a multiple number of basic radicals. On the contrary, I consider the complex silicates to be formed by simple silicates combined with one another, atom after atom, and that each step in this additive process produces a special silicate. I hope to make this notion clear by means of the formulæ that are given in TABLE I.

TABLE I. THEORETICAL CONSTITUTION OF SILICATES.

A. $MMO + nMSiO$	B. $SiSiO + nMSiO$	C. $4MSiO + nSiSiO$	D. $2MSiO + nSiSiO$	E. $MSiO + nSiSiO$
$M\,M\,O$	$Si\,Si\,O$			$M\,Si\,O$ k
$M^{3}SiO^{2}$ k	$M\,Si^{3}O^{2}$ k			$M\,Si^{3}O^{2}$ k
$M^{4}Si^{2}O^{3}$ k	$M^{2}Si^{4}O^{3}$ k		$M^{2}Si^{4}O^{3}$ d	$M\,Si^{5}O^{3}$ k
$M^{5}Si^{3}O^{4}$	$M^{3}Si^{5}O^{4}$ k		$M^{2}Si^{6}O^{4}$ d	$M\,Si^{7}O^{4}$
$M^{6}Si^{4}O^{5}$ k	$M^{4}Si^{6}O^{5}$ k	$M^{4}Si^{6}O^{5}$ d	$M^{2}Si^{8}O^{5}$ k	$M\,Si^{9}O^{5}$ k
$M^{7}Si^{5}O^{6}$ k	$M^{5}Si^{7}O^{6}$	$M^{4}Si^{8}O^{6}$ d	$M^{2}Si^{10}O^{6}$ d	$M\,Si^{11}O^{6}$
$M^{8}Si^{6}O^{7}$ k	$M^{6}Si^{8}O^{7}$ k	$M^{4}Si^{10}O^{7}$ k	$M^{2}Si^{12}O^{7}$ k	$M\,Si^{13}O^{7}$
$M^{9}Si^{7}O^{8}$	$M^{7}Si^{9}O^{8}$	$M^{4}Si^{12}O^{8}$ d	$M^{2}Si^{14}O^{8}$ d	$M\,Si^{15}O^{8}$
$M^{10}Si^{8}O^{9}$ k	$M^{8}Si^{10}O^{9}$ k	$M^{4}Si^{14}O^{9}$	$M^{2}Si^{16}O^{9}$ k	$M\,Si^{17}O^{9}$
$M^{11}Si^{9}O^{10}$	$M^{9}Si^{11}O^{10}$	$M^{4}Si^{16}O^{10}$d	$M^{2}Si^{18}O^{10}$d	$M\,Si^{19}O^{10}$
$M^{12}Si^{10}O^{11}$k	$M^{10}Si^{12}O^{11}$k	$M^{4}Si^{18}O^{11}$k	$M^{2}Si^{20}O^{11}$	$M\,Si^{21}O^{11}$
$M^{13}Si^{11}O^{12}$	$M^{11}Si^{13}O^{12}$	$M^{4}Si^{20}O^{12}$d	$M^{2}Si^{22}O^{12}$d	$M\,Si^{23}O^{12}$
$M^{14}Si^{12}O^{13}$k	$M^{12}Si^{14}O^{13}$	$M^{4}Si^{22}O^{13}$	$M^{2}Si^{24}O^{13}$k	$M\,Si^{25}O^{13}$
$M^{15}Si^{13}O^{14}$	$M^{13}Si^{15}O^{14}$	$M^{4}Si^{24}O^{14}$d	$M^{2}Si^{26}O^{14}$d	$M\,Si^{27}O^{14}$
$M^{16}Si^{14}O^{15}$	$M^{14}Si^{16}O^{15}$k	$M^{4}Si^{26}O^{15}$	$M^{2}Si^{28}O^{15}$k	$M\,Si^{29}O^{15}$

In this Table, $Si = 7{\cdot}5$. $O = 16$.

Column A.—It is supposed that a salt formed on the model of water = M,MO combines with a normal silicate = M,SiO, atom after atom, to produce the series of silicates that are here represented, and perhaps others that are beyond the limits of the Table.

Column B.—In this case it is supposed that an atom of anhydrous silica = Si,SiO combines with a normal silicate = M,SiO, atom after atom, to produce another series of silicates, necessarily differing in constitution from the former. The salts represented in Column A. all contain a small excess of base. Those of column B., an equal excess of acid.

Column C.—This column begins with the salt $M^{4}Si^{6}O^{5}$, which is supposed to be transferred from column B., and to have been formed by the addition of 4MSiO to SiSiO. The operation is now considered to be reversed, and the anhydrous acid SiSiO is added instead of the salt MSiO, atom by atom, to the salt $M^{4}Si^{6}O^{5}$, so as to produce the series of superacid salts given in this column.

Column D.—In this case the salt $M^{2}Si^{4}O^{3}$, transferred from column B., is increased by successive additions of SiSiO, till it forms the series of salts represented in the Table. Nearly all the varieties of "Glass" belong to the silicates that are inscribed in this column.

Column E.—The salts depicted in this column are produced by the combination of the neutral silicate = MSiO with successive atoms of anhydrous silica = SiSiO. The salts are consequently all acid salts.

The letter *k* frequently inserted in this Table intimates that the silicates so marked are *known* and of frequent occurrence. The letter *d* signifies that the salts are duplicates, and that similar, and more generally simpler, formulæ will be found in other columns of the Table.

The foregoing theory is now to be applied to the investigation of mineral silicates.

TABLE II. CONSTITUTION OF THE CHIEF VARIETIES OF KNOWN MINERAL SILICATES.

	A.		RAMMELSBERG'S FORMULÆ.		GRIFFIN'S FORMULÆ.
	Oxygen of the		B.	C.	D.
	Base.	Acid.	Silicates of Protoxides.	Silicates of Sesquioxides.	
1.	1	12	$RO,4SiO^3$	$R^2O^3,12SiO^3$	$R^2Si^{24}O^{13}$
2.	1	9	$RO,3SiO^3$	$R^2O^3, 9SiO^3$	$R\,Si^9\,O^5$
3.	1	6	$RO,2SiO^3$	$R^2O^3, 6SiO^3$	$R^2Si^{12}O^7$
4.	1	$4\frac{1}{2}$	$2RO,3SiO^3$	$2R^2O^3, 9SiO^3$	$R^4Si^{18}O^{11}$
5.	1	4	$3RO,4SiO^3$	$R^2O^3, 4SiO^3$	$R^2Si^8\,O^5$
6.	1	3	RO, SiO^3	$R^2O^3, 3SiO^3$	$R\,Si^3\,O^2$
7.	1	2	$3RO,2SiO^3$	$R^2O^3, 2SiO^3$	$R^2Si^4\,O^3$
8.	1	$1\frac{1}{2}$	$2RO, SiO^3$	$2R^2O^3, 3SiO^3$	$R^4Si^6\,O^5$
9.	1	1	$3RO, SiO^3$	R^2O^3, SiO^3	$R\,Si\,O$
10.	$1\frac{1}{3}$	1	$4RO, SiO^3$	$4R^2O^3, 3SiO^3$	$R^8Si^6\,O^7$
11.	$1\frac{1}{2}$	1	$9RO,2SiO^3$	$3R^2O^3, 2SiO^3$	$R^6Si^4\,O^5$
12.	2	1	$6RO, SiO^3$	$2R^2O^3, SiO^3$	$R^4Si^2\,O^3$
13.	3	1	$9RO, SiO^3$	$3R^2O^3, SiO^3$	$R^3Si\,O^2$

Rammelsberg's Nomenclature of the above Salts.

1, Fourfold silicates. 2, Threefold silicates. 3, Twofold silicates. 4, One-and-a-half fold, or sesquisilicates. 5, Four-thirds silicates. 6, Neutral or normal silicates. 7, Two-thirds, or half basic silicates. 8, Half or basic silicates. 9, One-third, or twofold basic silicates. 10, One-fourth, or threefold basic silicates. 11, Two-ninths, or three-and-a-half-fold basic silicates. 12, Sixth, or five-fold basic silicates. 13, Ninth, or eight-fold basic silicates.

In Rammelsberg's formulæ, $S = 22 \cdot 5$, $O = 8$,
In column D., $S = 7 \cdot 5$, $O = 16$.

TABLE II. is extracted from the "Einleitung" to Rammelsberg's *Handwörterbuch des chemischen Theils der Mineralogie*, Berlin, 1841, a work of great utility to all who study the chemistry of mineralogy.

According to Rammelsberg, who follows closely the system of Berzelius and the Berlin school of chemists and mineralogists, the silicates are divided into two categories—the silicates of protoxides, and the silicates of sesquioxides. These require the formulæ exhibited in the Table, in columns B. and C.

Innovations suggested. 1]. The atomic weight of silicon is to be reduced from 22·5 to 7·5. 2]. The atomic weight of oxygen is to be raised from 8 to 16. 3]. Every sesquioxide is to be considered to contain not R^2 but Rc^3, that is to say, not two combined basylous atoms, but three separable basylic atoms.

Effect of these Innovations. 1]. All the formulæ in column B. are transformed into those represented in column D. 2]. All the formulæ in column C. are transformed into those represented by column D., excepting that, instead of R., it is necessary to write Rc. By these transformations, the formulæ that represent basylic silicates are made to agree in atomic quantities with those that represent basylous silicates; whereas the formulæ of column C. are atomically three times as great as those of column B. These changes are of importance when considered in relation to what the chemical mineralogists, by a peculiar figure of speech, call *rational* formulæ; for it appears to me that the formulæ which commonly bear this title are singularly *irrational.*

TABLE III. (except the last column) is an extract from a larger Table of the same kind which is given in Rammelsberg's *Drittes Supplement zu dem Handwörterbuch des chemischen Theils der Mineralogie*, Berlin, 1847. The object of this Table is to show the relation that exists between the oxygen of the water, of the protoxides, of the sesquioxides, and of the anhydrous silicic acid contained in various classes of silicates. I have added the last column to show my view of the constitution of the same salts.

The alterations which I have made in the atomic weights of oxygen, silica, alumina, &c., necessarily affect the formulæ of the silicates to a great extent; but there is one consequence which is extremely remarkable, and, which, though it follows as a mathematical necessity, I had not foreseen, and first noticed with surprise.

Rammelsberg gives in this Table simple numbers to intimate the relations which the oxygen of the different radicals of the silicates bear to one another. These are stated in column B. of the Table.

Now, according to my atomic weights, these numbers, just as they stand, (and the observation applies to the whole of Rammelsberg's Table as well as to the short extract from it which is given as a specimen in Table III.)—these numbers express *the numbers of the radicals that are present in each silicate, and are collectively twice as great as the total number of the atoms of oxygen.* Consequently, the formation of formulæ in accordance with the radical theory is simple in the highest degree, as will be seen on comparing the formulæ in the last column of Table III. with the formulæ in the preceding columns.

Rammelsberg's formulæ as given in this Table are intended to show

TABLE III. RELATIONS OF THE OXYGEN IN NATURAL SILICATES.

A.	B.	C.	D.
Anhydrous Silicates of Protoxides:		RAMMELSBERG'S FORMULÆ.	GRIFFIN'S FORMULÆ.
	RO : SiO^3		
Gadolinite	1 : 1	$3YO , SiO^3$	$YSiO$
Williamite	1 : 1	$3ZnO , SiO^3$	$ZnSiO$
Lime, trisilicate . . .	1 : 3	CaO , SiO^3	$CaSi^3O^2$
Wollastonite	1 : 2	$3CaO , 2SiO^3$	$Ca^2Si^4O^3$
Tephroite	1 : 1	$3MnO, SiO^3$	$MnSiO$
Phenakite	1 : 2	$3BeO , 2SiO^3$	$G^2Si^4O^3$
Augite (manganesic) . .	1 : 2	$3MnO, 2SiO^3$	$Mn^2Si^4O^3$
Hydrous Silicates of Protoxides:			
	HO : RO : SiO^3		
Silicate of manganese . .	1 : 1 : 1	$3MnO, SiO^3, 3HO$	$H^3Mn^2Si^2O^3$
Dioptase	1 : 1 : 2	$3CuO , 2SiO^3, 3HO$	$HCucSi^2C^2$
Okenite	2 : 1 : 4	$5CaO , 4SiO^3, 6HO$	$H^4Ca^2Si^8O^7$
Anhydrous Silicates of Sesquioxides:			
	RO : SiO^3		
Cyanite	3 : 2	$3Al^2O^3, 2SiO^3$	$Alc^6Si^4O^5$
Zircon	1 : 1	Zr^2O^3 , SiO^3	$ZrSiO$
Agalmatolite	1 : 3	$Al^2O^3 , 3SiO^3$	$AlcSi^3O^2$
Bamlite	2 : 3	$2Al^2O^3, 3SiO^3$	$Alc^4Si^6O^5$
Bucholzite	1 : 1	Al^2O^3 , SiO^3	$AlcSiO$

TABLE III. Relations of the Oxygen in Natural Silicates—*continued.*

Hydrous Silicates of Sesquioxides:

	HO	:	R^2O^3	:	SiO^3	RAMMELSBERG'S FORMULÆ.	GRIFFIN'S FORMULÆ.
Worthite	1	:	6	:	5	$6Al^2O^3 \quad ,5SiO^3,3HO$	$HAlc^6Si^5O^6$
Erenite	2	:	1	:	2	$(Fe,Al)^2O^3,2SiO^3,6HO$	$H^4(Fec,Alc)^2Si^4O^5$
Cimolite	1	:	1	:	3	$Al^2O^3 \quad ,3SiO^3,3HO$	$H^2Alc^2Si^6O^5$

Anhydrous Silicates with both Protoxides and Sesquioxides:

	RO	:	R^2O^3	:	SiO^3		
Felspar	1	:	3	:	12	$KO \; , \; Al^2O^3,4SiO^3$	$KAlc^3Si^{12}O^8$
Albite	1	:	3	:	12	$NaO, \; Al^2O^3,4SiO^3$	$NaAlc^3Si^{12}O^8$
Leucite	1	:	3	:	8	$3KO,3Al^2O^3,8SiO^3$	$KAlc^3Si^8O^6$
Garnet	1	:	1	:	2	$3RO, \; R^2O^3 \; ,2SiO^3$	$RRcSi^2O^2$
Vesuvian	1	:	1	:	2	$3RO, \; R^2O^3 \; ,2SiO^3$	$RRcSi^2O^2$

Hydrous Silicates with both Protoxides and Sesquioxides:

	HO	:	RO	:	R^2O^3	:	SiO^3		
Natrolite	2	:	1	:	3	:	6	$NaO \; , \; Al^2O^3,2SiO^3, \; 2HO$	$H^2Na^1Alc^3Si^6O^6$
Scolezite	3	:	1	:	3	:	6	$CaO \; , \; Al^2O^3,2SiO^3, \; 3HO$	$H^6Ca^2Alc^6Si^{12}O^{13}$
Analcime	2	:	1	:	3	:	8	$3NaO,3Al^2O^3,8SiO^3, \; 6HO$	$H^2Na^1Alc^3Si^8O^7$
Laumunite	4	:	1	:	3	:	8	$3CaO \; ,3Al^2O^3,8SiO^3,12HO$	$H^4Ca^1Alc^3Si^8O^8$
Chabasite	6	:	1	:	3	:	9	$CaO \; , \; Al^2O^3,3SiO^3, \; 6HO?$	$H^5(K,Na,Ca)^1Alc^3Si^9O^9?$
Stilbite	6	:	1	:	3	:	12	$CaO \; , \; Al^2O^3,4SiO^3, \; 6HO$	$H^6Ca^1Alc^3Si^{12}O^{11}$

only the relative quantities of acids and bases contained in the respective salts, namely, the number of atoms of protoxides, of alumina, of silica, of water, &c. The formulæ which chemical mineralogists are pleased to call Rational, are given in the second column of Table IV.

TABLE IV. RATIONAL FORMULÆ OF THE SILICATES.

Anhydrous Silicates with one Protoxide.

	RAMMELSBERG'S FORMULÆ.	GRIFFIN'S FORMULÆ.
Trisilicate of lime	$CaO\ ,SiO^3$	$CaSi^3O^2$
Wollastonite	$3CaO\ ,2SiO^3$	$Ca^2Si^4O^3$
Gadolinite	$3YO\ ,SiO^3$	$YSiO$
Williamite	$3ZnO\ ,SiO^3$	$ZnSiO$
Augite (mangan.)	$3MnO\ ,2SiO^3$	$Mn^2Si^4O^3$
Phenakite	$3BeO\ ,2SiO^3$	$G^2Si^4O^3$
	Hydrous Silicates with one Protoxide.	
Meerschaum	$MgO\ ,SiO^3 + HO$	$H^2Mg^2Si^6O^5$
Dioptase	$3CuO\ ,2SiO^3 + 3HO$	$HCucSi^2O^2$
Silicate of manganese.	$3MnO\ ,SiO^3 + 3HO$	$H^2Mn^2Si^2O^3$
Okenite	$3CaO\ ,4SiO^3 + 6HO$	$H^4Ca^2Si^8O^7$
	Anhydrous Silicates with one Sesquioxide.	
Cyanite	$3Al^2O^3,2SiO^3$	$Alc^6Si^4O^5$
Zircon	$Zr^2O^3\ ,SiO^3$	$ZrSiO$
Agalmatolite	$Al^2O^3\ ,3SiO^3$	$AlcSi^3O^2$
Bamlite	$2Al^2O^3,3SiO^3$	$Alc^4Si^6O^5$
Bucholzite	$Al^2O^3\ ,SiO^3$	$AlcSiO$
	Hydrous Silicates with one Sesquioxide.	
Worthite	$(5Al^2O^3,SiO^3) + (Al^2O^3 + 3HO)$	$HAlc^6Si^3O^6$
Erenite	$Al^2O^3\ ,2SiO^3 + 6HO$	$H^4Alc^2Si^4O^5$
Cimolite	$Al^2O^3\ ,3SiO^3 + 3HO$	$H^2Alc^2Si^6O^5$
	Anhydrous Silicates with several Protoxides.	
Augite	$(Ca,Mg,Fe,Mn)^3O^3,2SiO^3$	$(Ca,Mg,Fe,Mn)^2Si^4O^3$
Olivine	$(Mg,Fe)^3O^3,SiO^3$	$(Mg,Fe)SiO$
Bustamite	$3CaO,2SiO^3 + 2(3MnO,2SiO^3)$	$Ca^2Mn^4Si^{12}O^9$
Troostite	$3FeO,2SiO^3 + 3(3MnO,SiO^3)$	$Fe^2Mn^6Si^{10}O^9$
Knebelite	$3FeO,SiO^3 + 3MnO,SiO^3$	$FeMnSi^2O^8$
	Anhydrous Silicates with several Sesquioxides.	
Beryl	$BeO^3,4SiO^3 + 2(Al^2O^3,2SiO^3)$	$G^2Alc^4Si^{16}O^{11}$
Ditto	$BeO^3,3SiO^3 + 2(Al^2O^3,3SiO^3)$	$GAlc^2Si^9O^6$
Euclase	$BeO\ ,SiO^3 + 2(Al^2O^3,SiO^3)$	$GAlc^2Si^3O^8$

Anhydrous Silicates with both Protoxides and Sesquioxides.

Felspar . . .	$KO\ ,SiO^3 + Al^2O^3,3SiO^3$	$KAlc^3Si^{12}O^8$
Albite . . .	$NaO,SiO^3 + Al^2O^3,3SiO^3$	$NaAlc^3S^{12}O^8$
Leucite . . .	$3KO,2SiO^3 + 3(Al^2O^3,2SiO^3)$	$KAlc^3Si^8O^6$
Vesuvian . . .	$3RO,SiO^3 + R^2O^3,SiO^3$	$RRcSi^2O^8$
Garnet . . .	$3RO,SiO^3 + R^2O^3,SiO^3$	$RRcSi^2O^8$

Hydrous Silicates with both Protoxides and Sesquioxides.

Stilbite . .	$CaO,SiO^3 + Al^2O^3,3SiO^3 + 6HO.$ $H^6Ca^1Alc^3Si^{12}O^{11}.$	*Rammelsberg.* *Griffin.*
Chabasite .	$(Ca,Na,K)O,SiO^3 + Al^2O^3,2SiO^3 + 6HO?$ $H^3(K,Na,Ca)^1Alc^3Si^9O^9?$	*Rammelsberg.* *Griffin.*
Scolezite . .	$CaO,SiO^3 + Al^2O^3,SiO^3 + 3HO.$ $H^6Ca^2Alc^6Si^{12}O^{13}.$	*Rammelsberg.* *Griffin.*
Natrolite . .	$NaO,SiO^3 + Al^2O^3,SiO^3 + 2HO.$ $H^2Na^1Alc^3Si^6O^6.$	*Rammelsberg.* *Griffin.*
Analcime .	$3NaO,2SiO^3 + 3(Al^2O^3,2SiO^3) + 6HO.$ $H^2Na^1Alc^3Si^8O^7.$	*Rammelsberg.* *Griffin.*
Laumonite .	$3CaO,2SiO^3 + 3(Al^2O^3,2SiO^3) + 12HO.$ $H^4Ca^1Alc^3Si^8O^8.$	*Rammelsberg.* *Griffin.*

TABLE IV. is an extract from a Table, comprehending all known silicates, which is given in the second volume of Rammelsberg's *Handwörterbuch*, already quoted. In the second column of this Table we have the so-called "rational formulæ" of the different silicates. This term is used to signify that we have here an account of what is commonly considered to be the proximate constitution of the substances.

In this Table, the rational formulæ are tolerably simple, excepting a few near the lower end; but the rational formulæ, constructed for many other minerals, are excessively complicated, as I shall presently show.

Let us endeavour to ascertain what is the actual value of these rational formulæ. Take the last in the list, that of Laumonite, as an example. This mineral, according to the information supplied in Table III., contains $3CaO$, $3Al^2O^3$, $8SiO^3$, $12HO$; and, in Table IV., these substances are put into the form of the following rational formulæ:

$$3CaO,\ 2SiO^3 + 3(Al^2O^3,\ 2SiO^3) + 12HO.$$

For this classification of the elements of the salt there is no evidence whatever. First, we have a salt in which three atoms of lime are assumed to be combined directly with two atoms of silicic acid, a mode of combination which agrees, indeed, with the law respecting what is called "combination in multiple proportions," but not with the laws of nature, which preside only over binary combinations; nor even with the law of Berzelius, that a salt must contain an atom of acid for every atom of oxygen which is present in the base. Then, one atom of this irregular salt is assumed to be combined directly with *three* atoms of another irregular salt in which one atom of alumina Al^2O^3 is stated to be combined with two atoms of silicic acid. Finally, there are twelve atoms of hydrogen set aside as water, without any attempt to prove that none of it exists in the salt in any other condition. The formula, therefore, is crammed with assumptions that are taken, without evidence, for facts, and its use is to make difficult of comprehension what otherwise is simple and clear—for

Take, on the contrary, the formula which is supplied for the same mineral by the radical theory, and which is

$$H^4Ca^1Alc^3Si^8O^8.$$

We can trust this formula, because the quantities are the result of analysis, and because every radical which it represents is known to be the equivalent of a volume of hydrogen. The compound contains eight simple silicates, which the formula makes known at a glance. Nothing would be gained by converting this unitary formula into a rational formula :—

Thus,	Or thus,	Or thus,
$Ca\ ,SiO$	$Ca\ SiO + HSiO$	$Ca\ ,SiO$
Alc,SiO	$AlcSiO + HSiO$	$3Alc,SiO$
Alc,SiO	$AlcSiO + HSiO$	$4H\ ,SiO.$
Alc,SiO	$AlcSiO + HSiO.$	
$H\ ,SiO$		
$H\ ,SiO$		
$H\ ,SiO$		
$H\ ,SiO.$		

These formulæ are useless, because all the information which they give is given at a glance by the unitary formula without needless display. And that great advantage results from giving to all the elements of the silicates such equivalents or atomic weights as level the whole to uniform simplicity. I do not admit of the existence of sesquioxides in silicates. I recognise therein the presence of salts formed on the model of water $= H,HO$; M,SiO, &c., and these alone.

Before I conclude the description of Laumonite, I may point out the difference that exists between the number of atoms which are demanded by Berzelius's notation, as employed by Rammelsberg, to represent the composition of that mineral and the number which is demanded by the radical theory.

ELEMENTS.	No. of Atoms in Rammelsberg's Formulæ.	No. of Atoms when corrected for new Atomic Weights.	No. of Atoms after Division by 3.
Ca	3	3	1
H	12	12	4
Al	6	9	3
Si	8	24	8
O	48	24	8
	77	72	24

A glance over the preceding Tables will show that this great reduction in the number of atoms takes place generally when the formulæ are recast to suit the radical theory; and it affords a powerful argument against those absurd and troublesome marplots—the sesquioxides, to the imagined presence of which the formulæ of the natural silicates are indebted for most of their extravagance. So long as chemical mineralogists persist in introducing sesquioxides into their formulæ of silicates; so long as they continue to patronize the doctrine of combination in multiple proportions; so long as they exclude from their comprehension the facts, that a silicate is a very simple salt, and that simple silicates combine with one another to make complex silicates; just so long must their "rational" formulæ be models of irrational modes of thought; just so long must they be fancy sketches,—based upon guesses, incapable of proof, unworthy of credit—puzzling, useless, obstructive.

COMPLEX SILICATES.

I will quote a few examples of complicated silicates, to show in what manner the new method of notation is qualified to meet the difficulties which they present.

AUGITE.—In the foregoing Tables I have quoted the manganese augite =

$3MnO,2SiO^3$ *Rammelsberg.*
$Mn^2Si^4O^8$ *Griffin.*

The manganese of this mineral is subject to be replaced by Ca, Mg, Fe, in various proportions, without any other change taking place in the composition of the mineral. Consequently these varieties are obtained:

a. $Mn^2 \; Si^4O^8$
b. $Ca^1Mg^1 \; Si^4O^8$
c. $Ca^1Fe^1 \; Si^4O^8$
d. $(Mn^3Fe^1)^2Si^4O^8$
e. $(Ca^1Mn^2)^2Si^4O^8$
f. $(Ca^3Mg^2Fe^1)^2 \; Si^4O^8$
g. $(Ca,Mg,Fe,Mn)^2Si^4O^8$

Examples of Rammelsberg's formulæ for these minerals:—

For *b.* $3MgO,2SiO^3 + 3CaO,2SiO^3$.
For *f.* $2(3MgO,2SiO^3) + 3(3CaO,2SiO^3) + 3FeO,2SiO^3$.

The condensed, or synoptical formula *f*, can be easily expanded to an analytical formula representing whole atoms, as follows:—

$$R^6Si^{12}O^9 = \left\{\begin{array}{l} 3Ca\ ,SiO. \\ 2Mg,SiO. \\ \ \ Fe\ ,SiO. \\ 3Si\ \ ,SiO. \end{array}\right.$$

In making this change of formula it is to be observed that the basic portion of formula *f*, namely $(Ca^3Mg^2Fe^1)^2$, signifies $Ca\frac{3}{6},Mg\frac{2}{6},Fe\frac{1}{6}$, of two atoms. If these fractions are made into whole numbers, the two atoms become six atoms, or are multiplied by three, in which case the silicon and the oxygen of the salt must also be multiplied by three.

CHABASITE.—Among many formulæ for this mineral, Rammelsberg gives the following:—

$$\begin{array}{l}[3Ca\,O,2SiO^3 + 3(Al^2O^3,2SiO^3) + 18HO] \\ + 2[3NaO,2SiO^3 + 3(Al^2O^3,2SiO^3) + 18HO].\end{array}$$

This formula contains the following ultimate atoms: 3Ca,6Na,54H, 18Al,24Si,162O, in all 267. When the atomic weights are corrected, they become 3Ca,6Na,54H,27Alc,72Si,81O; in all 243. When these corrected numbers are uniformly divided by 9, they produce the following formula:—

$$H^6(Na^2Ca^1)^1Alc^3Si^8O^9.$$

Gmelin's formula for this soda chabasite (which is also called Gmelinite) is = $2NaO,1CaO,3Al^2O^3,12SiO^2,18HO$. This formula is equivalent to the above. His formula for lime chabasite is $1NaO,3CaO,4Al^2O^3,16SiO^2, 24HO$, which produces the formula—

$$H^6(Na^1Ca^3)^1Alc^3Si^5O^9.$$

It is remarkable that Gmelin's two formulæ differ considerably in the proportions of silica, alumina, and water. Yet, when they are recast to suit the radical theory, they harmonize exactly, and prove that the actual differences between the two salts exist only in the quantities of sodium and calcium, all other elements remaining the same. The new formulæ show this fact significantly: the others conceal it.

Compare—

$$\begin{array}{l}H^6(Na^2Ca^1)^1Alc^3Si^8O^9, \\ H^6(Na^1Ca^3)^1Alc^3Si^8O^9,\end{array}$$

with—

$$\begin{array}{l}2NaO,1CaO,3Al^2O^3,12SiO^2,18HO. \\ 1NaO,3CaO,4Al^2O^3,16SiO^2,24HO.\end{array}$$

Upon first looking at the last two formulæ, it seems impossible that the minerals can agree precisely with one another in their proportions of hydrogen, aluminum, silicon, and oxygen; yet they do so, and by doing so they show how faulty is the existing theory which succeeds in smothering facts of such importance.

VESUVIAN. *Idocrase.* Gmelin gives the general formula $3CaO, 2SiO^2 + Al^2O^3,SiO^2$. This becomes reduced to $CaAlcSi^2O^2$.

Rammelsberg's formula is $3RO,SiO^3 + R^2O^3,SiO^3$; which yields the same result.

Gmelin gives the following formula, which exhibits the vicarious elements of this mineral.

$49CaO$, $5MgO$, $2Fe^2O^3$, $16Al^2O^3$, $54SiO^2$, with an atomic weight of 4125·2. This formula permits the following reduction:

$$\begin{array}{cccccccl}
Ca & Mg & Fe & Al & Si & O & & \\
49 & 5 & 4 & 32 & 54 & 216 & = & \text{Gmelin's atoms.} \\
\multicolumn{2}{c}{\underbrace{49 \quad 5}_{54}} & \multicolumn{2}{c}{\underbrace{6 \quad 48}_{54}} & \underbrace{108}_{108} & \underbrace{108}_{108} & = & \text{After correcting the atomic weights.} \\
\multicolumn{2}{c}{1} & \multicolumn{2}{c}{1} & 2 & 2 & = & \text{Division by 54.}
\end{array}$$

Hence the formulæ of this complicated salt is in round numbers $Ca^1Alc^1Si^2O^2$, or, with almost perfect accuracy:

$$Ca^8Mg^1Fec^1Alc^8Si^{18}O^{18} = \begin{cases} 8Ca\,SiO \\ 1\,MgSiO \\ 8AlcSiO \\ 1\,FecSiO. \end{cases}$$

FUCHSITE. Dr. Schafhäutl supplies the following formula for Fuchsite (*Gmelin's Chemistry*, iii. 450).

$$\begin{array}{rlrl}
38 & (3KO, SiO^3) + & 2 & (3NaO,\ SiO^3) + \\
360 & (Al^2O^3,SiO^3) + & 24 & (Cr^2O^3,\ 3SiO^3) + \\
18 & (MgO, SiO^3) + & 12 & (Fe^2O^3,\ 3SiO^3) + \\
9 & CaF^2. & &
\end{array}$$

Bravo! This is the *ne plus ultra* of chemical accuracy! So charming a performance deserves an attentive examination. The ultimate atoms here represented are 114K, 6Na, 18Mg, 24Fe, 48Cr, 720Al, 526Si, 2904O, 9Ca, 18F; in all 4387. When the atomic weights are corrected, the number of atoms becomes 4383, and they permit of arrangement into simple silicates in accordance with the radical theory as follows:

$$\begin{array}{rl}
\left.\begin{array}{rl} 1080 & Alc,SiO \\ 72 & Crc,SiO \\ 36 & Fec,SiO \end{array}\right\} & = 1188 = 9(Alc^{30}Crc^{2}Fec^{1})^1,SiO \\
\left.\begin{array}{rl} 18 & Mg,SiO \\ 114 & K\ ,SiO \\ 6 & Na\ ,SiO \end{array}\right\} & = \ \ 138 = 1(\ K^{19}Na^{3}Mg^{1}\ )^1,SiO \\
126 \ \ Si\ ,SiO & = \ \ 126 = 1 \quad Si \qquad\qquad ,SiO \\
\hline
1452 & \text{Neutral silicates.}
\end{array}$$

$$= (KNaMg)^1(AlcCrcFec)^9Si^{11}O^{11} + \tfrac{1}{10}CaF;$$

nearly equal to $KAlc^9Si^{12}O^{11} + \frac{1}{10}CaF$, and not very far from AlcSiO.

These details show that Dr. Schafhäutl's giant formula is of no more use than the shortest possible formula. The affectation of marvellous accuracy in analysis which this formula displays, goes for nothing, because we know that such a degree of accuracy is beyond the power of human manipulation. The short formula gives us an idea of the composition of this mineral. The comprehension of Dr. Schafhäutl's formula is about as easy as the comprehension of the distances of the fixed stars, expressed in lines or millimetres.

These examples are sufficient to show in what manner I propose to formulate the natural silicates. I double the atomic weight of the oxygen; reduce the atom of silicon to one-third of Berzelius's number or to one-half of Gmelin's number; and dismiss the sesquioxides in a body. The formulæ, written on the model of $(R^xRc^ySi^z)^2O^1$, then become simple and uniform.

It may perhaps be objected that the formulæ which I recommend for the designation of the silicates are unitary, whilst I have in other sections of the work strongly objected to the use of unitary formulæ. I reply to that objection, that the formulæ of the silicates are unitary by necessity, and that nevertheless they differ entirely in nature from the unitary formulæ which are often applied to the hydrocarbon salts. In the next section I shall show that the unitary formulæ $C^{16}H^{32}O^2$ exhibit the composition of sixteen different salts, which contain sixteen different basic radicals, and sixteen different acid radicals; the presence and composition of not one of which can be inferred from the inspection of the formula $C^{16}H^{32}O^2$. No such difficulty can possibly occur from the use of the formulæ which I have recommended for the silicates.

I do not enter upon the consideration of the Classification and Nomenclature of the Silicates. The number of vicarious atoms which they contain renders the construction of a convenient System and the application of a correct Nomenclature a matter of difficulty, for the discussion of which no space is left in this volume.

With this section I conclude my investigation into the constitution of the polybasic and conjugated acids; not because the subject is exhausted, but because the figure at the top of this page warns me of the necessity of bringing the discussion to a conclusion. I set out with the expression of the opinion, that every normal salt is a binary compound, consisting of one basic radical and one acid radical. I hope that the facts and arguments which I have advanced in the course of the discussion will have satisfied the reader that this opinion was advanced with reason. It is a point of considerable importance in chemical philosophy. Conjugated and polybasic acids, like complicated organic bases, are obstacles to the progress of chemical science. I have endeavoured to expose the fallacies upon which they are founded, and I shall rejoice if that exposure helps to destroy their credit.

The Aluminous and Aluminic Radicals.

In the Table of Atomic Weights, I have ascribed two equivalents to Aluminum: the aluminous equivalent, $Al = 13.65$, and the aluminic equivalent, $Alc = 9.1$; the latter corresponding to the ferric atom, and the former to the ferrous atom.

I have been induced to suggest two equivalents of aluminum, in consequence of the results of the recent experiments of Mr. Crum, one of which is represented in the following diagram:

$$\left.\begin{array}{l} \mathrm{AlcSO^2} \\ \mathrm{AlcSO^2} \quad + \\ \mathrm{AlcSO^2} \\ \mathrm{Pb,C^2H^3O^2} \\ \mathrm{Pb,C^2H^3O^2} \\ \mathrm{Pb,C^2H^3O^2} \end{array}\right\} \text{Produce} \left\{\begin{array}{l} \left.\begin{array}{l} \mathrm{Pb,SO^2} \\ \mathrm{Pb,SO^2} \\ \mathrm{Pb,SO^2} \end{array}\right\} + \\ \mathrm{Al,C^2H^3O^3} \\ \mathrm{Al,C^2H^3O^2} \\ \quad \mathrm{C^2H^3O^2} \end{array}\right.$$

Namely, an atom of the compound commonly called Tersulphate of alumina, mixed with 3 atoms of acetate of lead, produce 3 atoms of sulphate of lead, 1 atom of binacetate of alumina, and 1 atom of free acetic acid. That is to say, as much alumina as saturates 3 atoms of sulphuric acid, can saturate only 2 atoms of acetic acid.

I am inclined to explain this result, by supposing that the 3 aluminic atoms in the sulphate are converted during the process of double decomposition, into two aluminous atoms, which take up two atoms of acetic acid, and leave the third atom free. The free acid is left, however, without a base. If it takes H from the water of the solution to supply that want, either oxygen must be liberated, or peroxide of hydrogen be dissolved in the mixture. Thus:

$$\mathrm{C^2H^3O^2} + \mathrm{HHO} = \mathrm{H,C^2H^3O^2} + \mathrm{HO}.$$

$$\text{or else, } \begin{array}{l} \mathrm{C^2H^3O^2} \\ \mathrm{C^2H^3O^2} \end{array} + \mathrm{HHO} = \begin{array}{l} \mathrm{H,C^2H^3O^2} \\ \mathrm{H,C^2H^3O^2} \end{array} + \mathrm{O}.$$

This assumption of two different radicals of aluminum is countenanced by other facts detected by Mr. Crum, namely, that there are two hydrates of alumina possessed of very different properties, and that the acetate of alumina can be so altered by heat as to lose its power of acting as a mordant. I am not able to say, that the aluminous atom, as distinct from the aluminic atom, certainly exists; but Mr. Crum's researches certainly point towards such a conclusion, and are difficult of explanation on the ordinary theory of salts.

My friend, Mr. W. D. Clark, has communicated to me another fact which seems also to point to the conclusion, that there are two different oxides of aluminum. If a quantity of calico, mordanted with alumina, is boiled with a quantity of madder *a little too small* to dye the cloth of a desired colour, the operation entirely fails. The cloth does not obtain a *faint shade* of the desired colour, corresponding with the *insufficient quantity of madder*, but there is produced an entirely different compound by which the cloth is sometimes spoiled. This result seems to show it to be possible to convert the Mordanting oxide of aluminum into the Non-mordanting oxide even after its combination with vegetable fibre. These facts are quite in accordance with the theory which I have advanced respecting the transmutability of basylous and basylic radicals.

Thoughts on the Origin and Metamorphoses of Organic Radicals.

A great proportion of the solid mass of plants consists of compounds which contain carbon united to those proportions of oxygen and hydrogen that are necessary to compose water. C + HHO. We can account for the production of such compounds by assuming that water and carbonic acid combine together, under separation of the quantity of oxygen which is not required for these organic compounds. The separation of the oxygen, and the combination of the residues appear to take place, under circumstances which I shall state more explicitly hereafter, in the cells upon the leaves of the plants which are exposed to sunshine. COO + HHO give off OO and produce CHHO. This product appears to me to be the oxide of the important neutral radical which I have called VINYL = CH^2. Accordingly, I propose to give to this compound the formula CH^2O, and to call it *Vinylate*.

The relation borne by vinylate to certain important neutral vegetable substances may be expressed as follows:

CH^2O. Vinylate. This is the composition of Fructose, sugar of fruits, or grape sugar.
$C + (CH^2O)^4$. Dried milk sugar.
$C + (CH^2O)^4 + HHO$. Milk sugar, undried = CH^2O.
$C + (CH^2O)^5$. Starch. Cellulose. Woody fibre (flax, cotton, paper).
$C + (CH^2O)^5 + HHO,HHO$. Glucose. Starch sugar = $(CH^2O)^6 + Aq$.
$C + (CH^2O)^2$. Lignin, but which is of variable composition.
$C + (CH^2O)^7$. Inulin.
$C + (CH^2O)^{11}$. Cane sugar. Arabin (gum arabic).

The above important compounds, comprehending woody fibre, the gums, starches, and sugars—the solid structure of trees, and the sweet juices of fruits, seem to be all reducible to compounds of vinylate united, atom after atom, to a single atom of carbon $= C + CH^2 + CH^2 + CH^2$, &c.

When these compounds lose their single atom of carbon, they are all reduced to the condition of vinylate or grape sugar. Thus, when cane sugar is acted on by an alkali or an acid, the atom of carbon is removed and grape sugar remains. So also when starch or woody fibre is acted on by an acid, the atom of carbon is removed, and grape sugar or vinylate remains. It would be an important discovery in the chemical arts, could we find a method of combining with a multiple of grape sugar this odd atom of carbon which converts it into starch or into cane sugar. But at present our chemical power is limited to the *decomposition* of the higher orders of organic compounds. We cannot *recompose* them.

It appears, from these considerations, that vinylate, or the simplest form of sugar, is the nutritive principle of plants, the material which is employed to form the various radicals which the different orders of plants, and the different organs of each plant, demand for their support. The metamorphoses of the sugar probably takes place in the cells of the green leaves, of the blossoms, or of the fruit; in those parts, namely, where it is acted upon by the light and heat of the sun, and where it is able to disengage its superfluous oxygen. It is difficult to form a precise idea of the processes by which this change of sugar into radicals, or into salts composed of radicals, is effected. Probably the walls of the cells in which the operations occur consist of azotic substances, which give them the power of galvanic batteries. It is possible that the azotes of those cells may be endowed with very active powers, and may, according to certain conditions of osmose, regulated by light, heat, air, and water, run incessantly backwards and forwards through its various characters of amidogen-, ammonium-, and cyanogen-former, and thus repeat in each particular cell those processes of construction and transformation of radicals which I have endeavoured to describe and classify in treating of the theory of azotic radicals. Millions of such cells exist in a tuft of grass or the twig of a plant. It is known that they are azotic; it is known that azotic cells have a powerful action even on dead vegetable matter (as in fermentation); it is known that plants grow vigorously after a thunder-storm; and these conditions are all favourable to the idea that the conversion of sugar into compound radicals is the work of azote, acting with intense electrical force in the cells of plants exposed to air and light.

When the oxygen is disengaged, the residue of the components of sugar can produce an astonishing variety of radicals which differ according to the wants of the plants, or to other special circumstances which lead to their production. I will quote a few instances.

a). When jargonelle pears are in course of ripening, the compound which gives them their odour and flavour is produced by the metamorphosis of 7 atoms of CH^2O minus O^5. The product is $C^5H^{11},C^2H^3O^2$, which I may call amyla acetylete, or the acetate of amyl, a compound which is now made artificially, and sold under the name of pear-oil or essence of jargonelles. In the production of this essence, one atom of sugar is divided into $H + CH$. 5 atoms of CH^2 then become attached to the odd atom of H, producing amyl = C^5H^{11}, and 1 atom of CH^2 to the atom of CH, producing acetyl = C^2H^3. For this salt, and for all the salts of the vinyl series, only two atoms of oxygen are required, so that all the rest of the oxygen belonging to the atoms of vinylate which are required to produce the salt must be disengaged.

All the ethereal essences which give fragrance and flavour to ripening fruits appear to be produced in the same manner. Thus:—

$C^5H^{10}O^2$, the residue left by the expulsion of O^3 from five atoms of sugar, produces $CH^3,C^4H^7O^2$ = methyla butyrylete, or the butyrate of methyl, which is the essence of the apples called rennets.

$C^{10}H^{20}O^2$ produces $C^5H^{11},C^5H^9O^2$ = amyla valerylete, or valerianate of amyl, the essence of other varieties of apples.

$C^6H^{12}O^2$ produces $C^2H^5,C^4H^7O^2$ = ethyla butyrylete, or the butyrate of ethyl, the oil which yields the flavour of the pine-apple.

$C^{11}H^{22}O^2$ produces $C^2H^5,C^9H^{17}O^2$ = ethyla pelargylete, or the pelargonate of ethyl, which is the essence of quinces.

$C^9H^{18}O^2$ produces $C^2H^5,C^7H^{13}O^2$ = ethyla œnanthylete, or œnanthylate of ethyl, an oil which gives flavour to Hungarian wine. It is probable that the flavour of many wines may thus be imitated.

The metamorphoses of sugar into these fragrant essences is only a single example selected from a multitude of possible changes. The Table of Examples on the following page exhibits a more enlarged view of these interesting metamorphoses.

PRODUCTS OF THE METAMORPHOSES OF SUGAR.

From $C^4H^8O^2$ = 4 atoms of Sugar minus O^2.	From $C^8H^{16}O^2$ = 8 atoms of Sugar minus O^6.	From $C^{12}H^{24}O^2$ = 12 atoms of Sugar minus O^{10}.	From $C^{16}H^{32}O^2$ = 16 atoms of Sugar minus O^{14}.
$H, C^4H^7O^2$	$H, C^8H^{15}O^2$	$H, C^{12}H^{23}O^2$	$H, C^{16}H^{31}O^2$
$C^1H^3, C^3H^5O^2$	$C^1H^3, C^7H^{13}O^2$	$C^1H^3, C^{11}H^{21}O^2$	$C^1H^3, C^{15}H^{29}O^2$
$C^2H^5, C^2H^3O^2$	$C^2H^5, C^6H^{11}O^2$	$C^2H^5, C^{10}H^{19}O^2$	$C^2H^5, C^{14}H^{27}O^2$
$C^3H^7, C^1H^1O^2$	$C^3H^7, C^5H^9O^2$	$C^3H^7, C^9H^{17}O^2$	$C^3H^7, C^{13}H^{25}O^2$
	$C^4H^9, C^4H^7O^2$	$C^4H^9, C^8H^{15}O^2$	$C^4H^9, C^{12}H^{23}O^2$
	$C^5H^{11}, C^3H^5O^2$	$C^5H^{11}, C^7H^{13}O^2$	$C^5H^{11}, C^{11}H^{21}O^2$
	$C^6H^{13}, C^2H^3O^2$	$C^6H^{13}, C^6H^{11}O^2$	$C^6H^{13}, C^{10}H^{19}O^2$
	$C^7H^{15}, C^1H^1O^2$	$C^7H^{15}, C^5H^9O^2$	$C^7H^{15}, C^9H^{17}O^2$
		$C^8H^{17}, C^4H^7O^2$	$C^8H^{17}, C^8H^{15}O^2$
		$C^9H^{19}, C^3H^5O^2$	$C^9H^{19}, C^7H^{13}O^2$
		$C^{10}H^{21}, C^2H^3O^2$	$C^{10}H^{21}, C^6H^{11}O^2$
		$C^{11}H^{23}, C^1H^1O^2$	$C^{11}H^{23}, C^5H^9O^2$
			$C^{12}H^{25}, C^4H^7O^2$
			$C^{13}H^{27}, C^3H^5O^2$
			$C^{14}H^{29}, C^2H^3O^2$
			$C^{15}H^{31}, C^1H^1O^2$

From $C^{30}H^{60}O^2$ = 30 atoms of Sugar minus O^{28}.

$H, C^{30}H^{59}O^2$	Hydra	melissylete.
$C^1H^3, C^{29}H^{57}O^2$	Methyla	?
$C^2H^5, C^{28}H^{55}O^2$	Ethyla	?
$C^3H^7, C^{27}H^{53}O^2$	Propyla	cerotylete.
$C^4H^9, C^{26}H^{51}O^2$	Butyla	?
$C^5H^{11}, C^{25}H^{49}O^2$	Amyla	?
$C^6H^{13}, C^{24}H^{47}O^2$	Hexyla	?
$C^7H^{15}, C^{23}H^{45}O^2$	Heptyla	?
$C^8H^{17}, C^{22}H^{43}O^2$	Octyla	?
$C^9H^{19}, C^{21}H^{41}O^2$	Nonyla	behenylete.
$C^{10}H^{21}, C^{20}H^{39}O^2$	Decatyla	arachylete.
$C^{11}H^{23}, C^{19}H^{37}O^2$	Endecatyla	balenylete
$C^{12}H^{25}, C^{18}H^{35}O^2$	Dodecatyla	stearylete
$C^{13}H^{27}, C^{17}H^{33}O^2$	?	margarylete
$C^{14}H^{29}, C^{16}H^{31}O^2$	?	palmitylete
$C^{15}H^{31}, C^{15}H^{29}O^2$	?	benylete.
$C^{16}H^{33}, C^{14}H^{27}O^2$	Cetyla	myristylete.
$C^{17}H^{35}, C^{13}H^{25}O^2$	?	cocinylete.
$C^{18}H^{37}, C^{12}H^{23}O^2$	?	laurylete.
$C^{19}H^{39}, C^{11}H^{21}O^2$	?	margaritylete.
$C^{20}H^{41}, C^{10}H^{19}O^2$	?	rutylete.
$C^{21}H^{43}, C^9H^{17}O^2$	?	pelargylete.
$C^{22}H^{45}, C^8H^{15}O^2$	?	caprylete.
$C^{23}H^{47}, C^7H^{13}O^2$	?	œnanthylete.
$C^{24}H^{49}, C^6H^{11}O^2$	?	caproylete.
$C^{25}H^{51}, C^5H^9O^2$	?	valerylete.
$C^{26}H^{53}, C^4H^7O^2$	?	butyrylete.
$C^{27}H^{55}, C^3H^5O^2$	Ceryla	propionylete.
$C^{28}H^{57}, C^2H^3O^2$	?	acetylete.
$C^{29}H^{59}, C^1H^1O^2$	?	formylete.

The sign ? indicates that the radicals are undiscovered or unnamed.

According to this Table, the metamorphoses of 4 atoms of sugar can produce 4 different complete salts, each with a different acid radical and a different basic radical. Which of these four compounds is producible on any given occasion, depends upon the wants of the plant, upon its power of metamorphoses, or upon other causes which it is impossible to specify.

In the same manner, 8 atoms of sugar produce 8 different salts. 12 atoms of sugar produce 12 different salts. 16 atoms produce 16 salts. 30 atoms produce 30 salts. Hence it appears, that any number of atoms of sugar can produce by metamorphoses an equal number of different salts.

Several particulars resulting from these observations require notice.

a). In all the groups of this Table, every acid radical is combined with a different basic radical. This fact proves that these radicals are exchangeable or equivalent, and that, whatever their composition, however high or however low they stand in the scale, their power of neutralisation is the same. Every radical in the series is chemically equivalent to every other radical, and the replacement of the most complex by the most simple is attended by no change in neutrality. In the year 1845, Professor Hofmann expressed opinions that were antagonistic to these facts. "By organic base, in the strict sense of the word, I understand, with Liebig, that class of compound, azotised bodies, which possess all the properties of basic metallic oxides. The oxides of ethyle, methyle, &c. are not included, as the most common character of salts is wanting in their compounds, viz., the replacement of their acids by other acids, and their bases by other bases." *Memoirs of the Chemical Society*, ii. 268. In the year 1857, Professor Hofmann may probably be induced to abandon these opinions, opposed as they are to innumerable facts which prove that ethyl, methyl, &c., are true radicals, each precisely equivalent in basic power to the most complicated ammoniums.

b). We perceive the utter worthlessness of *unitary formulæ* as applied to organic salts. The formula $C^{16}H^{32}O^{2}$ applied to a compound of the vinyl series, signifies SIXTEEN DIFFERENT SALTS, and every similar unitary formula signifies *as many different salts as it contains atoms of carbon;* of which fact, the unitary formula gives no intimation.

c). We have a complete exposition of Berzelius's doctrine of *metamerism*, a term by which he indicated "the case in which the compound atoms of two chemical compounds containing the same elementary atoms, and for the most part in the same proportions, are nevertheless made up of different proximate elements." We see in the opposite Table 5 complete metameric groups, and we perceive both the cause and the extent of the metamerism, and can therefore complete other groups at our pleasure.

d). The note of interrogation in Group 5 of the Table, shows the position and composition of the radicals of the vinyl group which have not yet been recognised. Of course, these radicals are unnamed, which accounts for the blanks in the names of the salts of this group.

I take this opportunity of suggesting, that as known radicals are becoming numerous, it will soon be found expedient to have some kind of *Systematic Names*, to identify them and to intimate their composition. In this work I have used the names of radicals as I found them, though many are objectionable, and the series must soon be greatly enlarged. This point may therefore be recommended to chemists as one that requires early consideration. It is quite possible to designate the precise composition of all possible hydrocarbons, the composition of which does not exceed $C^{100}H^{100}$, by names of two syllables, easy to distinguish and to recollect, and not liable to run into confusion with those terminal numerals, which I have recommended to be used as enumerators of radicals and of oxygen when combined into salts.

I proceed now to direct the reader's attention to the relations which the organic radicals bear to one another. I have thrown the most important of them into the Table which is printed on the opposite page, and which, though imperfect, may serve as the first rough sketch of that chart of organic radicals which I have described at page 81, as being so desirable an acquisition.

CLASSIFICATION OF RADICALS. If this Table were correct and complete, it would present a classification of radicals. The radicals placed in the vertical columns of this Table are far more closely connected together than those which occur in the horizontal lines. The latter, indeed, present a uniform quantity of carbon, and this uniformity induced Gmelin to plan the arrangement of organic bodies in his great system, in accordance with the quantity of carbon alone. It has proved to be very disadvantageous to his book; for the relations of the radicals that are similar only in the number of atoms of carbon, are far less important than those which characterise the radicals of each vertical group in this Table. Had he taken such groups for his standards, and had he arranged the salts of each radical on the plan of his inorganic chemistry, the organic chemistry would have been as easy of reference as the inorganic part, whereas it is now extremely complicated and troublesome.

TOTAL NUMBER OF ORGANIC RADICALS. It is a remarkable circumstance, that the number of well-known Organic Radicals does not greatly exceed the number of Inorganic Radicals, page 28.

RELATIONS OF THE ORGANIC RADICALS.

A.	B.	C.	D.	E.
nCH^2+H^1 nCH^2-CH	nCH^2-H^1 nCH^2+CH	nCH^2-H^2 nCH^2+C^1	nCH^2-H^3	nCH^2-H^4
C^1H^3k	C^1H^1k	C^1H^0k		
C^2H^5k	C^2H^3k	C^2H^2k	C^2H^1k	C^2H^0k
C^3H^7k	C^3H^5k	C^3H^4k	C^3H^3k	C^3H^2
C^4H^9k	C^4H^7k	C^4H^6k	C^4H^5k	C^4H^4kB
$C^5H^{11}k$	C^5H^9k	C^5H^8k	C^5H^7k	C^5H^6kB
$C^6H^{13}k$	$C^6H^{11}k$		C^6H^9	C^6H^8
$C^7H^{15}k$	$C^7H^{13}k$		C^7H^{11}	$C^7H^{10}kB$
$C^8H^{17}k$	$C^8H^{15}k$		$C^8H^{13}k$	C^8H^{12}
C^9H^{19}	$C^9H^{17}k$		C^9H^{15}	$C^9H^{14}kB$
$C^{10}H^{21}$	$C^{10}H^{19}k$		$C^{10}H^{17}k$	
$C^{11}H^{23}k$	$C^{11}H^{21}k$		$C^{11}H^{19}$	
$C^{12}H^{25}k$	$C^{12}H^{23}k$		$C^{12}H^{21}$	
$C^{13}H^{27}k$	$C^{13}H^{25}k$		$C^{13}H^{23}$	
$C^{14}H^{29}$	$C^{14}H^{27}k$		$C^{14}H^{25}$	
$C^{15}H^{31}k$	$C^{15}H^{29}k$		$C^{15}H^{27}k$	
$C^{16}H^{33}k$	$C^{16}H^{31}k$		$C^{16}H^{29}k$	
$C^{17}H^{35}$	$C^{17}H^{33}k$		$C^{17}H^{31}$	
$C^{18}H^{37}$	$C^{18}H^{35}k$		$C^{18}H^{33}k$	
$C^{19}H^{39}$	$C^{19}H^{37}k$		$C^{19}H^{35}k$	
$C^{20}H^{41}$	$C^{20}H^{39}k$		$C^{20}H^{37}$	
$C^{21}H^{43}$	$C^{21}H^{41}k$		$C^{21}H^{39}$	
$C^{22}H^{45}$	$C^{22}H^{43}$		$C^{22}H^{41}k$	
$C^{23}H^{47}$	$C^{23}H^{45}$			
$C^{24}H^{49}$	$C^{24}H^{47}$			
$C^{25}H^{51}$	$C^{25}H^{49}$			
$C^{26}H^{53}$	$C^{26}H^{51}$			
$C^{27}H^{55}k$	$C^{27}H^{53}k$			
$C^{28}H^{57}$	$C^{28}H^{55}$			
$C^{29}H^{59}$	$C^{29}H^{57}$			
$C^{30}H^{61}k$	$C^{30}H^{59}k$			

(*Continued on the next page.*)

RELATIONS OF THE

F. nCH^2-H^5	G. nCH^2-H^6	H. nCH^2-H^7	I. nCH^2-H^8	K. nCH^2-H^9
C^3H^1	C^3H^0kB			
	C^4H^2k	C^4H^1	G^4H^0	
	C^5H^4kB	C^5H^3k		C^5H^1
		C^6H^5k		C^6H^3
		C^7H^7k		C^7H^5k
		C^8H^9k		C^8H^7k
		$C^9H^{11}k$		C^9H^9k
		$C^{10}H^{13}k$		$C^{10}H^{11}k$
				$C^{11}H^{13}$

EXPLANATION OF THE TABLE EXHIBITING THE RELATIONS WHICH THE ORGANIC RADICALS BEAR TO ONE ANOTHER.

I have arranged the radicals in vertical columns according to the method of grouping them which is most in use among organic chemists; that is to say, in agreement with the formulæ nCH^2+H^1, nCH^2-H^2, nCH^2-H^3, &c.

I wish it, however, to be understood, that these headings do not represent my opinion of the Constitution of the radicals that are placed below them. If these formulæ represent the *result*, they certainly do not represent the *order*, of Nature's proceedings. If Nature has to produce a Hill, she certainly does not in the first instance produce a Mountain and then cut it down. The early crystallographers supposed that if Nature wanted to produce an octahedron, she first produced a cube and then cut off all its corners till nothing remained of its original faces, but a mathematical point in the centre of each. In like manner, these organic formulæ appear to assume, that if Nature desires to produce a radical, such as cumyl for example, she first combines together ten atoms of vinyl into the compound $C^{10}H^{20}$, and then takes away H^9, and leaves the desired result $C^{10}H^{11}$. I renounce that method of explanation, believing Nature's process to be, in all cases, that of adding atom to atom one by one till she reaches the desired point. She never overworks herself, in order to be forced to undo what she has done amiss.

The horizontal lines in the Table represent the radicals which agree in possessing the same quantity of carbon.

Throughout the Table, proceeding from above downwards, every

ORGANIC RADICALS.

L.	M.	N.	O.	P.
$n\mathrm{CH}^2-\mathrm{H}^{10}$	$n\mathrm{CH}^2-\mathrm{H}^{11}$	$n\mathrm{CH}^2-\mathrm{H}^{12}$	$n\mathrm{CH}^2=\mathrm{H}^{13}$	$n\mathrm{C}+\mathrm{H}$ $n\mathrm{C}+\mathrm{CH}$
				C^1H^1
				C^2H^1k
				C^3H^1
				C^4H^1
C^5H^0				C^5H^1
C^6H^2kB	C^6H^1	$C^6 H^0$		C^6H^1
C^7H^4kB	C^7H^3k		$C^7 H^1$k	C^7H^1k
	C^8H^5		$C^8 H^3$k	
	C^9H^7k	$C^9 H^6$ kB	$C^9 H^5$	
		$C^{10}H^8$	$C^{10}H^7$k	
		$C^{11}H^{10}$kB		

radical exceeds the one above it by the addition of CH^2, proving that the same relation which holds true among the radicals of the vinyl series, quoted in columns A. and B., holds equally true in all the other series; the differences being confined to the constitution of the first radical, or starting point of each group. This principle of a common difference among a series of radicals is what Gerhardt calls HOMOLOGY. Every column in the Table is, in his terms, an *Homologous series.*

The radicals which are marked k in the Table are known to chemists, if not in an isolated state, at least in some form of combination. Those marked B. are the radicals of bibasic acids: strictly speaking many of these should be rejected from this Table, because they are actually double radicals, and appear again in their single form in other groups in the Table. See columns C. and E., and the article on the succinic group of salts, page 441.

Most of the radicals in the Table have an uneven number of atoms of hydrogen, and only those which have that composition seem to possess an atomic measure when they form part of gaseous salts. The salts of vinyl CH^2, of succinyl C^2H^2, of salicyl C^7H^4, when in the gaseous state measure only as much as is due to the radicals with which they are in combination.—See page 96.

GROUP A. *Basic Radicals of the Vinyl Group*; and

GROUP B. *Acid Radicals of the Vinyl Group.*

These two groups have undergone so complete an investigation in the preceding pages, particularly in the articles between pages 49 and 81, and just now in the note on the metamorphoses of sugar, that I need not go into farther details. The radicals of this series which are known to chemists are marked k. The others will probably soon be found. I have pointed out (pages 73 to 77, page 407, &c.) several processes by which the radicals of this series can be successively reduced from basic to acid, and from acid to basic, by the alternate removal of H^2 and C^1; and there is no doubt that a continuation of researches of this character will soon produce the radicals that are now unknown, among the products of the decomposition of the radicals which are placed higher in the series.

Buckton's recently published interesting researches respecting the acids of the succinic group (see page 454), prove that much can be successfully accomplished by acting on the higher members of the organic compounds. But the energy of Buckton's agent—hot nitric acid—is such as to shatter the complex radicals too readily into fragments. It is desirable to employ milder processes, and thus to reduce the complex radicals, step by step, down the scales of basic to acid, and acid to basic, until those intermediate radicals which have hitherto escaped detection, but the places and composition of which are indicated in the Table, are produced and converted into characterising salts. All the compound radicals which are lower in composition than $C^{30}H^{61}$ will certainly be discovered if they are carefully sought for.

GROUP C. *Radicals of the Succinic Group.*—Monobasic. They are described at page 441. It is assumed of the radicals of this group, that they are formed by the successive addition of atoms of vinyl to one atom of carbon; every step in that additive process producing a new radical. The primary radical C^1 and its first compound C^2H^2, both have the peculiarity of losing their atomic measure when they form gaseous salts. The other members of the series do not produce gaseous salts.

GROUP D. The salts of this group differ among themselves by the common difference of CH^2, and they contain as an invariable element, or common ingredient, the radical C^2H which stands at the head of the list. This radical is equivalent to $CH + C$, which are the characteristics of the salts of Groups B and C, and therefore the radicals of Group D are each equal to a radical belonging to Group B combined with another belonging to Group C. Yet they are all monobasic, and we must consequently consider them to be single radicals. The known radicals of this series are as follows: C^2H. Maleyl; fumaryl; dyl; see the article on the Malic Group, page 411, and the Citric Group, page 424. C^3H^3. Acryl; pyruvyl; tryl; see the article on the Citraconates, page 438. C^4H^5, the radical of isotartaric acid. C^5H^7, the radical of camphoric acid and angelic acid. C^8H^{13}, conyl, probably the radical contained in conia. $C^{10}H^{17}$, the radical of campholic acid. $C^{15}H^{27}$, the radical of moringic acid, procured from the oil of ben. $C^{16}H^{29}$, the radical of hypogeic acid, a compound produced during the saponification of arachidic acid, which is formed by the radical arachyl = $C^{20}H^{39}$ of the vinyl series. $C^{18}H^{33}$, oleyl, the radical of oleic acid. $C^{19}H^{35}$, the radical of doeglinic acid, which is procured from a species of sperm whale; it is remarkable for being an oil which contains no glycerine. $C^{22}H^{41}$, the radical of erucic or brassic acid, derived from the oil of mustard.

The radicals of this series appear to be nearly all produced by the application of heat to substances that belong to the vinyl series, and their relation to the radicals of that series is easily perceived. Thus

Glycyl (or allyl) = $C^{3}H^{5} - H^{2}$ = acryl $C^{3}H^{3}$.
Stearyl = $C^{18}H^{35} - H^{2}$ = oleyl $C^{18}H^{33}$.
Oleyl = $C^{18}H^{33} - C^{1}$ = margaryl $C^{17}H^{33}$.
Acetyl = $C^{2}H^{3} - H^{2}$ = fumaryl $C^{2}H^{1}$.

In short, all the radicals of this group may be considered to be convertible into acid radicals of the vinyl series, Group B, by the addition of H^{2}, or the subtraction of C^{1}. Probably they all existed in the living plant or animal as members of the vinyl series, and owe the forms in which they are shown in Group D, to the metamorphoses effected by the chemical reactions that were employed to effect their separation from other substances. The whole of the series D, except $C^{2}H$ may also be considered as compounds of CH^{2}, repeated *n* times, with one atom of pyruvyl $C^{3}H^{3}$ constant in all, and it is remarkable that this last atom is that which is frequently produced when other more complex radicals are subjected to heat. Pyruvic acid = $H,C^{3}H^{3}O^{3}$ is equal to a compound of formic acid = H,CHO^{2} wlth pyrogallic acid = CH,CHO, all of which are nearly allied in their chemical characters.

Group E. With the exception of the starting radical C^{2}, which represents the acid radical of the mellates, all the radicals of this group are double radicals of Group C. They form double salts, and appear to have no title to be called simple radicals. See page 441.

Group F. I find no radicals which can with any certainty be ascribed to this group.

Group G. C^{3} is the acid radical of the mesoxalic acid, which has the formula $H^{2},C^{3}O^{3}$, and is therefore apparently bibasic; but this acid belongs to an important series of compounds, the products of the decomposition of cyanyl, which I have not examined in this volume. I consider this formula to represent a double salt. $C^{4}H^{2}$ is phtalyl, the radical of phtalic acid, which is commonly said to be bibasic, but which is actually monobasic; its salts corresponding to the formula $M,C^{4}H^{2}O^{2}$. This fact is completely confirmed by the constitution of the phtalamides, phtalimides, and phtalaniles of the series. $C^{5}H^{4}$ is the assumed radical of the citraconic acid, which I have shown to be a double acid; see page 438.

Group H. The known radicals of this series, except the first two on the list, are so important that they have undergone repeated discussions in the preceding pages. $C^{5}H^{3}$ is the radical of the pyromeconic acid. $C^{6}H^{5}$ is phenyl. The same composition is commonly ascribed to citryl, but the arguments which I have used in the article on the citrates at page 424, prove that citryl is not a radical. C^7H^7 is toluenyl (and anisol?) C^8H^9 is xylenyl. C^9H^{11} is cumenyl. $C^{10}H^{13}$ is thymyl. These radicals are all of the basic order, and act in salts as basic radicals without requiring any oxygen beyond that which is proper to the normal salts of the acid radicals with which they combine.

In tracing the homology of this group of radicals from below upwards, we come to the radical C^4H^1, which does not belong to the vinyl series. I have endeavoured to account for the origin of this radical in Group P, where I suppose that a series of radicals are produced by the successive addition of atoms of C^1 to one atom of H, taken as the primary nucleus. The radicals of Group H belong to the series of essential oils, which are produced by nature in fruits and seeds under circumstances where not only oxygen but water itself could be given off during the conversion of sugar into the oils demanded by the wants of the living plant. In that way atoms of carbon could be added to salts of the vinyl series till the composition demanded by the plant was completed, though it is impossible to form a clear idea of the manner in which this operation takes place.

The artificial formation of some of these radicals takes place in accordance with facts that have been frequently referred to. Thus, indyl = C^8H^3 the basis of indigo, can by chemical means be deprived of C^2 and be made to receive an addition of H^2, producing C^6H^5 phenyl. These two operations, viz., the abstraction of C^2, or the addition of H^2, frequently take place among radicals. Here the two actions occur simultaneously and render the process more complicated yet not more mysterious.

GROUP I. I can find no well-ascertained Examples in agreement with this formula.

GROUP K. The known radicals of this group are C^7H^5 = benzyl, and perhaps spiryl; see page 455; C^8H^7 = toluyl and anisyl; C^9H^9 = styryl; $C^{10}H^{11}$ = cumyl. These radicals belong to the resinous or aromatic series, and are nearly related to those of Group H, both in properties and in composition, and their origin is probably liable to a similar method of explanation. On comparing the radicals of the two groups as they stand in the same horizontal lines of the Table, we perceive that they bear to one another, in pairs, precisely the relations of basic radicals to acid radicals, the common difference, like that between the two orders of vinyl radicals, situated on the same horizontal lines in the Table being H^2.

Thus, Toluenyl $C^7H^7 - H^2 = C^7H^5$, benzyl.
Xylenyl $C^8H^9 - H^2 = C^8H^7$, toluyl.
Cumenyl $C^7H^{11} - H^2 = C^9H^9$, styryl.
Thymyl $C^{10}H^{13} - H^2 = C^{10}H^{11}$, cumyl.

or, changing the operation in *terms*, though not in *essence*, we have

Phenyl $C^6H^5 + C^1 = C^7H^5$, benzyl.
Toluenyl $C^7H^7 + C^1 = C^8H^7$, toluyl.
Xylenyl $C^8H^9 + C^1 = C^9H^9$, styryl.
Cumenyl $C^9H^{11} + C^1 = C^{10}H^{11}$, cumyl.
Thymyl $C^{10}H^{13} + C^1 = C^{11}H^{13}$, ?

And in effect these figures accurately express the corresponding chemical powers of the respective radicals; for those of Group H are basic while those of Group K are acid. Those of Group H go into salts as basic radicals without carrying additional oxygen with them; but those of Group K, when they act as basic radicals demand an additional supply of oxygen, and that quantity differing according to the acid properties of each special radical: thus, benzyl, which forms benzoates with O^2 takes with it O^1 extra when it acts as a basic radical; while anisyl, which forms anisates with O^4, takes with it O^2 extra when it acts the part of a basic radical. These details afford interesting illustrations of the truth of the general principle which I have advanced, namely, that the difference which exists between basic radicals and acid radicals is expressed either by C^1 or H^2, since these proportions of carbon or of hydrogen are sufficient to change the class of any radical, whatever may be its ultimate composition. The question of basicity or acidity never depends upon the *absolute quantity* of carbon or hydrogen that happens to be present in any radical, but entirely upon the *relative proportions* of those elements.

Group L. The known radicals of this group are only two in number, C^6H^2, the radical of the bibasic comenic acid, respecting the composition of which I have great doubts, and C^7H^4, which is salicyl, a bibasic radical, the salts of which I have investigated at page 455. It is by no means improbable that C^7H^4 represents two radicals instead of one, and that the salicylic acid is a double acid and not a bibasic acid; but the reactions of the salts do not afford any clue to the unravelment of this mystery.

Group M. The formula C^7H^3 represents the radical of gallic acid, which, in accordance with this formula is tribasic. I do not believe that that is the true account of the gallates, but I am unable to give a better account of them. The recorded experiments are not sufficient to give clear and satisfactory ideas respecting their composition. When gallic acid is heated, it produces a compound which is called pyrogallic acid. The formula of this compound appears to me to be CH, CHO, according to which it is not an acid at all, but a suboxide of formyl. In the new nomenclature this salt would be called formyla formylate. It acts as a powerful reducing agent, because one atom of it requires four atoms of oxygen for the decomposition. Thus:—

$$CH, CHO + O^4 = HHO + CO^2 + CO^2.$$

The other known radical of this group, C^9H^7, is cinnamyl, the radical of the cinnamic acid $H,C^{9}H^{7}O^{2}$. It takes O^{1} extra when it acts as a basic radical.

GROUP N. The formula $C^{9}H^{6}$ represents the radical of Hofmann's recently discovered bibasic insolinic acid = $HH,C^{9}H^{6}O^{4}$. When this acid is distilled, it yields benzoic acid. This reaction, with the composition of the formula, its bibasic nature, its large quantity of oxygen, and the even number of its atoms of hydrogen, all concur to induce me to consider the insolinic acid to be a double acid, probably composed of

$H,C^{7}H^{5}O^{2}$ = benzoic acid.
$H,C^{2}H^{1}O^{2}$ = dylic acid? See page 411.

The other formula of this group $C^{11}H^{10}$ represents the radical of sinapic acid, $H^{2}C^{11}H^{10}O^{5}$, a bibasic acid, the existence of which is rather suppositional than proved.

GROUP O. The known radicals of this group are as follow:—

$C^{7}H^{1}$ is the radical of the meconic acid, which is assumed to be tribasic, but I cannot say that this tribasic character rests upon satisfactory grounds. The meconates are $HHH, C^{7}H^{1}O^{7}$. When heated, they give off CO^{2} and become comenates = $HH, C^{6}H^{2}O^{5}$, when the comenates are heated, they give off CO^{2}, and become pyromeconates = $H,C^{5}H^{3}O^{3}$. Thus, throughout the series the acid radical contains in all 8 atoms. When C^{1} goes off, H^{1} comes to replace it. This proceeding is repeated. The H^{1} which thus replaces the disengaged C^{1} is a basic radical; and as the change proceeds in the acid radical, the acid radical of the salt, which first is tribasic, changes to bibasic, and then to monobasic. I expect that we shall by-and-by have a very different account of these metamorphoses.

$C^{8}H^{3}$ is the formula of indyl, which I have fully discussed in the article on indigo, page 257. It is worthy of remark, that this radical is, like meconyl, liable to undergo two remarkable changes, without diminution of the collective number of its ultimate atoms. Thus:—

Indyl, $C^{8}H^{3} - C^{1} + H^{1} = C^{7}H^{4}$, salicyl.
Indyl, $C^{8}H^{3} - C^{2} + H^{2} = C^{6}H^{5}$, phenyl.

I wish I could understand or explain the nature of these changes.

The last formula of this group is $C^{10}H^{7}$ = naphtyl, a radical which has so often come under our notice, that I need scarcely enter upon any discussion respecting it. Like phenyl, it is singularly addicted to form part of amidogens and ammoniums, in which it acts exactly in the same manner as phenyl. Hofmann has recently made a "new base" by means of this radical, which however is merely a framework upon which to hang a new set of hard names.

Monaphthalamine (for so he calls it) has the following constitution: $C^{42}H^{17}N^{3}$, which, as I take it, means that it is a double amidogen salt:

$$\text{A.}\left\{\begin{array}{l} ZH,C^{10}H^7;\ H \\ ZH,C^{10}H^7;\ CN \end{array}\right\} = \text{Naphtylac hydra cum naphtylac cyana.}$$

The salts of this "base" are as follows:—

$$\text{B.}\left\{\begin{array}{l} ZH^3,C^{10}H^7;\ Cl \\ ZH,C^{10}H^7;\ CN \end{array}\right\} = \text{Naphtylam chlora cum naphtylac cyana.}$$

$$\text{C.}\left\{\begin{array}{r} ZH,C^{10}H^7;\ CN \\ ZH,C^{10}H^7;\ CN \\ H;\ CN \end{array}\right\} = \text{Bis naphtylac cyana cum hydra cyana.}$$

$$\text{D.}\left\{\begin{array}{r} C^{10}H^7;\ CNO \\ C^{10}H^7;\ CNO \\ H;\ CN \end{array}\right\} = \text{Bis naphtyla cyanate cum hydra cyana.}$$

Hofmann's names for these salts are as follow:—B. Hydrochlorate of menaphthalamine = $C^{42}H^{17}N^3HCl$. C. Dicymenaphthalamine = $C^{46}H^{17}N^5 = C^{42}H^{17}N^3 + Cy^2$. D. Menaphthoximide = $C^{46}H^{15}N^3O^4$. He tells us that "menaphthoximide may be viewed as binoxalate of menaphthalamine *minus* 4 equivalents of water—

$$\underbrace{C^{42}H^{17}N^3HC^2O^4,HC^2O^4}_{\text{Binoxalate of menaphthalamine.}} - 4HO = \underbrace{C^{46}H^{15}N^3O^4}_{\text{Menaphthoximide.}};$$

and this view is corroborated by the deportment of the substance with potassa, which reproduces menaphthalamine and oxalic acid." *Proceedings of the Royal Society*, 1856, viii. 12.

I see nothing to prove that binoxalate of menaphthalamine ever had any existence, and I account for the last-mentioned reaction thus:—

$$\left.\begin{array}{r} \text{D.}\left\{\begin{array}{c} C^{10}H^7,CNO \\ C^{10}H^7,CNO \\ H,CN \end{array}\right. \\ \text{Potash}\left\{\begin{array}{c} H,KO \\ H,KO \end{array}\right\} \end{array}\right\} = \left\{\begin{array}{l} \left.\begin{array}{l} ZH,C^{10}H^7;\ H \\ ZH,C^{10}H^7;\ CN \end{array}\right\} = \text{A.} \\ \qquad — \\ \left.\begin{array}{l} K,CO^2 \\ K,CO^2 \end{array}\right\} = \text{Oxalate of potash.} \end{array}\right.$$

According to this view, menaphthalamine is a "new base," but not a new radical. It is only a new double salt, of the same nature as melaniline, which I have investigated at page 291. The introduction of what chemists call a "new base" is by no means to be considered as the discovery of a new radical. Lest the reader should at any time feel a difficulty in distinguishing a "base" from a "radical," let me remind him, that a *radical* is the *equivalent of one volume of hydrogen or of chlorine*, and possesses the saturating capacity proper to one volume of either; whereas a *base* is a heterogeneous mixture of atoms, which have no specific chemical duty to do, and which, as to number, are without limit, and, as to collocation, are without order. A radical may be compared to a thorough-trained soldier, who forms part of a system, is accustomed to discipline, and acts according to order. A base is a Bashi Bazouk, who is thoroughly untrained, who despises system, is unaccustomed to discipline, and is obedient only to the dictates of caprice. Any harum-scarum fellow answers for a Bashi Bazouk. Any conglomeration of atoms serves as a base. But a soldier must be a man who knows his duty and does it. A radical is a collection of atoms determinate as to quantity, orderly as to system, and always prepared to fulfil the functions which its position in the system it pertains to imposes upon it. In short, the difference between a radical and an organic base is like the difference between order and disorder.

GROUP P. This group, purely hypothetical, is inserted to account for the starting radicals in the columns D, F, H, K, M, O. I suppose that originally C^1 combines with H^1 or with C^1H^1, and that C^1 is then added atom after atom, till the several products which are exhibited in this column are produced; after which these radicals, acting as units, combine with successive atoms of CH^2 to produce the radicals which form the groups given in the different columns of the Table.

It is however just as easy to imagine that the radicals are first formed in accordance with the methods of production explained in reference to the vinyl radicals, and that these radicals then become subject to the successive additions of atoms of C^1. Or, on the other hand, some of them may be explained as being derived from radicals actually belonging to the vinyl series, by the artificial expulsion of a limited quantity of hydrogen. Thus terbasic glycerine = $H,H,H,C^3H^5O^3$ when deprived of HHO produces monobasic allylic acid = $H,C^3H^3O^2$, and when deprived of a second atom of HHO, it produces acrolein = H,C^3H^3O, in which we have an acid radical belonging to Group D. This last reaction differs in no respect, or degree, as respects the change in the radicals, from that which converts alcohol into aldehyde.

$$H,C^2H^5O - H^2 = H,C^2H^3O.$$

It is unquestionably a fact that the basic radicals are reducible to acid radicals by the abstraction of H^2, and it does not seem unreasonable to assume that the acid radicals themselves may be capable of snstaining successive abstractions of H^2, by artificial means, so as to produce the more highly carbonised radicals. Thus C^5H^{11} may become in succession $C^5H^9,C^5H^7,C^5H^5,C^5H^3$; and in like manner C^9H^{19}, may become C^9H^{17}, $C^9H^{15},C^9H^{13},C^9H^{11},C^9H^9,C^9H^7,C^9H^5$. These are points that are capable of experimental investigation, and are not likely to pass unheeded.

Besides these groups of radicals, I have endeavoured to trace the existence of others, but without useful results. For example, the Group $nC+CH^2$ produces C^4H^2 and C^6H^2, but no other known radicals; and the Group $C+nH$ produces CH,CH^2,CH^3, and then stops, as there is no known hydrocarbon radical with a greater proportion of H to C than is found in methyl.

On looking over these homologous groups of radicals, the remarkable trikes us, that the greater proportion of them are produced direct process from sugar or vinylate, and that most of the others seem to be derived by processes, which, though indirect, are short and obvious, from the same substance. Sugar in the form of CH^2O is the raw material which life in plants works up into the innumerable finished manufactures which vegetables expose to the admiration of mankind and among which animal life finds sustenance.

The METAMORPHOSES of Organic Radicals have been so often discussed in the preceding pages, that I need only refer to the main facts.

Acid radicals can be transformed into basic radicals by the abstraction of C^1. Thus:

Formyl $= C^1H^1 - C^1 = H =$ hydrogen.
Acetyl $= C^2H^3 - C^1 = C^1H^3 =$ methyl.
Allyl $= C^3H^5 - C^1 = C^2H^5 =$ ethyl.
Benzyl $= C^7H^5 - C^1 = C^6H^5 =$ phenyl.

On the other hand, basic radicals can be reduced to acid radicals by the abstraction of H^2. These matters have been so fully discussed at page 74, in the article at page 399, and incidentally on several other occasions, that I need enter now into no details.

When hydrides of acid radicals are sealed up in glass tubes with a saturated solution of hydracids in water, and heated to 212° F., they are changed into chlorides of the corresponding basic radicals. In this way acid radicals are converted into basic radicals by the addition of H^2, instead of the abstraction of C^1. Berthelot thus produced the following metamorphoses:

Propionyla hydra . $C^3H^5,H + HCl = C^3H^7,Cl$ Propyla chlora.
Valeryla hydra . $C^5H^9,H + HCl = C^5H^{11},Cl$ Amyla chlora.
Capryla hydra . . $C^8H^{15},H + HCl = C^8H^{17},Cl$ Octyla chlora.
Palmityla hydra . $C^{16}H^{31},H + HCl = C^{16}H^{33},Cl$ Cetyla chlora.

And, by acting in the same manner on what he calls Ethylene by hydrobromic acid, he produced bromide of ethyl:

$$\underbrace{CH^2 + CH^2}_{\text{Vinyl, 2 atoms.}} + HBr = \underbrace{C^2H^5,Br}_{\text{Ethyla broma.}}$$

By a process quite equivalent to this, the hydrides of amidogens are converted into chlorides of ammoniums. Thus:

$$ZH^2H + HCl = ZH^4,Cl.$$

Many transformations of this description will be seen under the head of Aniline, page 274.

Akin to this process is also that by which the amids of oxygen acids are converted into normal ammonium salts. Thus:

$$ZH^2,CO + HHO = ZH^4,CO^2.$$

These transformations have been illustrated by innumerable examples during the investigation of the azotic radicals.

Another method of metamorphoses consists in converting complex radicals which contain many times CH^2, into radicals of a simpler kind, by the action of nitric acid. An example of this mode of procedure is referred to in the article on the Anchoates at page 454.

The doctrine of *Vice-Radicals* has been fully explained and illustrated in the preceding pages. A vice-radical is a hydrocarbon in which the hydrogen has been more or less replaced by Cl, Br, I, N, S, or a metal, and which, notwithstanding that replacement, still acts the part of a radical.

Many acid radicals can be made to act as basic radicals, provided they are supplied with a certain excess of oxygen. This excess of oxygen is demanded by such radicals even when they form part of an ammonium.

Many other processes of metamorphoses might be noticed, and have been already described in this work; but they are reducible to three classes:—

a). They change a basic radical into the acid radical next below it by the abstraction of H^2, or into the acid radical next above it by the addition of C^1.

b). They change an acid radical into the basic radical next below it by the abstraction of C^1, or into the basic radical next above it by the addition of H^2.

c). They reduce a complex radical to one or more radicals of a simpler constitution.

What chemists have need of at present, are processes which will enable them to imitate the operation of nature, in forming complex radicals from simpler kinds by the addition of atoms of CH^2 to a nucleus, or by combining together ready-formed atoms of the simpler kind to produce those of the complex kind. That power is, however, more to be desired than expected.

The metamorphoses of organic radicals which depend upon the transmutations of azote, and those which take place in living animals, I must decline to touch upon. They are too important to be slighted, and I have not considered them sufficiently to be warranted in pronouncing clear opinions upon them. The theories which I have advanced in this work respecting the existence, the nature, the properties, the origin, and the transformations of hydrocarbon radicals must, if they represent what is true, have a great effect in changing the commonly-received formulæ of azotic and animal substances, which are extremely unsatisfactory. The "unitary" formulæ which I have quoted in page 167 are, confessedly, declarations of ignorance of anything beyond the knowledge afforded by destructive analyses; while the "rational" formulæ generally met with are in the highest degree fanciful—such as

$$20(C^{36}H^{25}N^{4}O^{10} . 2HO) + 8H^{2}NS + H^{2}NP = \text{albumen of eggs.}$$
$$(C^{36}H^{25}N^{4}O^{11} . 2HO) + H^{2}NS + H^{2}NP = \text{fibrin of ox-blood.}$$
$$6(C^{36}H^{25}N^{4}O^{11} . 2HO) + S^{2}O^{2} = \text{fibrin-protein.}$$

I copy these formulæ from Lehmann's *Physiological Chemistry*, 1851, vol. i., where they are attributed to Mulder. The application of the radical theory to these compounds would no doubt produce formulæ of a much simpler character; but the investigation is one for which I cannot afford time.

Daltonism. The Atomic Theory. The Law of Combination in Multiple Proportions.

The "LAWS OF CHEMICAL COMBINATION" at present recognised by chemists are explained by Professor Miller as follows:—

"The relative proportion in which the different elements unite is regulated by fixed laws. These important laws, which are three in number, regulate the mode of combination of every known chemical compound. These are usually termed *the laws of chemical combination.*

1. "The first of these laws is the law of *Definite Proportions*, which, although of great simplicity, is one of fundamental importance to the science of chemistry. This law may be stated in very few words; it is as follows:—*In every chemical compound the nature and the proportions of its constituent elements are fixed, definite, and invariable.*"

2. "The second law of combination is usually termed the law of *Multiple Proportions.* It frequently happens that a pair of elementary bodies unite together in more than one proportion. The compounds so obtained are very different from each other; but there is still a uniformity in the plan upon which these compounds are formed, and the proportions of the two elements in each are very simply related. The law of multiple proportion may be thus stated:—*If two elements, A and B, unite together in more proportions than one, on comparing together quantities of the different compounds, each of which contains the same amount of A, the quantities of B will bear a very simple relation to each other;* such as

$$A + B, \quad A + 2B, \quad A + 3B, \quad A + 4B, \text{ \&c.};$$
$$\text{or, } 2A + 3B, \quad 2A + 5B, \quad 2A + 7B, \text{ \&c.};$$
$$\text{or, } A + B, \quad A + 3B, \quad A + 5B, \text{ \&c.}$$

Water, for instance, is a compound of oxygen and hydrogen; in 100 parts, by weight, there are, as already mentioned, 88·9 of oxygen and 11·1 of hydrogen. But there is another compound of oxygen and hydrogen known to chemists, termed the peroxide of hydrogen. By analysis it has been found that 100 parts of this body contain 94·1 of oxygen, and 5·9 of hydrogen. Now, on comparing together the quantities of oxygen which in these two compounds are united with an equal quantity, say 1 part of hydrogen, it is evident that in water, for 1 of hydrogen there are 8 of oxygen:

Since 11·1 : 88·9 :: 1 : 8.

And by a similar process it is seen that in the peroxide of hydrogen, for 1 part of hydrogen 16 of oxygen are present:

5·9 : 94·1 :: 1 : 16.

The quantity of oxygen combined with the hydrogen in the peroxide, being just double what it was when combined with the same quantity of hydrogen in water.

"A similar simple proportion between the quantities of the combining elements is found to hold good in every series of compounds formed by the union of two elements with each other. A certain quantity of one of the elements combines with a certain quantity of the other; in the next compound with twice as much as in the first; in the next with three times; in the next with four times that quantity, and so on. Sometimes the proportion is rather less simple, two proportions of one element combining with 3, 5, 7, or 9 of the other.

"This important law, which was first clearly established by Dalton, was explained by him by means of his *Atomic Theory*. Upon this hypothesis, the ultimate particles of each element are considered to be uniform in size and in weight for that element, and moreover to be incapable of farther subdivision. When bodies unite chemically, as the particles of the same element have all the same size and relative weight, the proportions in which they combine must be *definite;* and farther, if they unite in several different proportions, those proportions must be simply related to each other. Thus, water may be conceived to be a compound in which each separate particle of hydrogen is united with a single particle of oxygen; and peroxide of hydrogen would be represented as consisting of a combination of two particles of oxygen with each particle of hydrogen.

3. "This explanation will simplify the consideration of the third law, which is usually known as the *Law of Equivalent Proportions*. It may be stated as follows:—*An elementary substance, in combining with other elements, does so in a fixed proportion, which may be represented numerically.*

"If a certain proportion of an element, A, unites with certain other fixed quantities of different elements, B, C, D, &c., to form compounds AB, AC, AD, &c., the quantities of B, C, and D, which so unite with A will also be the quantities in which B and C, C and D, combine to form compound BC, BD, CD, &c." *Elements of Chemistry*, 1855, i. 12.

I devote the following pages to the exposition of facts, which show that the "*law of combination in multiple proportions*," the main-spring of the atomic theory, is unsound; that it is founded on a *fallacy*, and that, being fallacious, it necessarily leads to practices which are injurious to chemical philosophy.

The particular fallacy to which I allude is this:

a). IT IS a *fact*, that compounds exist which contain uneven numbers of the elements of which they are composed; such as

$$A + A + B; \; A + B + B; \; A + A + B + B + B.$$

b). It MAY BE a *fact*, that these compounds are constituted by the direct combination of all the atoms of one kind with all the atoms of the other kind. Thus:

$$AA + B; \; A + BB; \; AA + BBB.$$

c). It MAY BE a *fact*, that chemical combination never takes place except between single atoms of elements, or single equivalents of compounds, in which case the compounds which contain the number of atoms of A and B specified above, must make certain intermediate compounds. Thus:

$$A + AB; \; AB + B; \; AB + (AB + B).$$

The supposition marked *c* is in accordance with the electro-chemical theory. The supposition marked *b*, sets the electro-chemical theory at defiance; for as it is against all experience in electrolytic researches, that a compound represented by the formula A^2B^3, should be separated into AA, going off at one electrode, and BBB going off at the other; so I conceive it to be equally opposed to electro-chemical probability, that combination should take place directly between such clumps of atoms as AA and BBB.

But, the law of combination in multiple proportions is founded upon the supposition which is marked *b*. It takes for granted, but never pretends to offer the slightest proof, that combination actually occurs between multiple proportions of atoms. Now, if the supposition which is marked *c* should prove to be true, that which is marked *b* must necessarily be false, and in that case the law of combination in multiple proportions is false; while so long as it remains *uncertain*, whether supposition *b* or supposition *c* is true, it is a fallacy to reason as if supposition *b* was absolutely known to be true. The law of combination in multiple proportions is therefore unsound and not to be trusted.

We are indebted for this law to Dalton, and we have only to look into the writings of that philosopher to find how feeble and uncertain is the evidence upon which the law is founded. Indeed, while Dalton laid down this law respecting the combination of elements in multiple proportions, he confessed that he was totally unable to determine *how much of any single element constituted a single proportion.* If he was unable to determine how much constituted a single proportion, surely he was incompetent to determine how much constituted a multiple proportion, and if, while in this state of ignorance respecting the very premises of his argument, he made laws which implied the possession of accurate knowledge, though, by accident, the laws might prove to be true, there was far greater chance of their proving to be false.

I copy the following statement from the *Memoirs of John Dalton*, by Dr. W. C. Henry, published by the Cavendish Society in 1854.

"It must be conceded, *in limine*, that the great atomic generalisation does not stand on the solid basis of induction, which is here, in its first announcement, claimed for it, by its illustrious Author. Even assuming the existence of elementary atoms of different weights (itself obviously hypothetical), we are not in possession of the mathematical elements necessary to infer 'from the relative weights in the mass, the relative weights of the ultimate particles or atoms of the bodies.' All that is *certainly* established, is, the proportions by weight in which bodies combine,—in Dalton's words, 'the relative weights of the simples, which constitute a compound.' Now these relative or equivalent weights are, on the atomic hypothesis, the products of the atomic weights into the number of atoms. Consequently, to infer the unknown atomic weights from the known equivalents, we require the number of atoms. But these numbers cannot be *ascertained* in the case of a single chemical compound. They can only be gathered, according to grounds of *probability*, from various relations and arguments, to be hereafter enumerated. This general statement may be made clear by a single example. It is established by experiment, that 8 parts by weight of oxygen combine with 1 part by weight of hydrogen. Let W and w represent the unknown atomic weights of oxygen and hydrogen, and N and n the numbers of atoms present in each mass respectively,

$$\text{Then } NW = 8 \text{ and } nw = 1$$
$$\text{And } W = \frac{8}{N} \text{ and } w = \frac{1}{n}$$

W and w cannot be inferred without knowing N and n.

"Mr. Dalton derived the numerical value of N and n from a supposition, which, though highly probable, is still nothing more than an hypothesis. He maintained, that the most stable combinations must be binary, and that when only a single combination of two elements was known, it was probably binary. Water was the only compound of oxygen and hydrogen then known to exist. He therefore regarded it as constituted of one atom of oxygen and one atom of hydrogen. Hence

N and n being identical, the atomic weights will be represented by the equivalents 8 and 1.

$$\text{For } W : w :: \frac{8}{N} \quad \frac{1}{n} :: 8 : 1.$$

To bring out more distinctly the hypothetical character of this reasoning, it may be observed, that Berzelius never admitted water to be a 'binary compound;' but inferred from its being constituted of 1 part by *volume* of oxygen and 2 parts of hydrogen by *volume*, that it consists of 1 atom of oxygen united with 2 atoms of hydrogen. Substituting 1 and 2 for N and n in the above formula, we obtain 16 as the weight of the atom of oxygen, hydrogen being unity.

"Mathematical certainty is, therefore, not attainable (even if we admit the existence of atoms of different weights) in any single atomic determination. It is in vain to contend for a higher degree of evidence than that of *probabilities*, in support of the atomic hypothesis itself; or still less of special calculations of the weights of elementary and compound atoms.

"After this distinct avowal, it will be more satisfactory to recal Dalton's mode of estimating the number of atoms in compounds, in his own words, as expressed in the Appendix to his second volume, 1827, and as therefore conveying his matured views and final teaching.

"'The second object of the atomic theory, namely, that of investigating the *number* of atoms in the respective compounds, appears to me to have been little understood, even by some who have undertaken to expound the principles of the theory. When two bodies, A and B, combine in multiple proportions; for instance, 10 parts of A combined with 7 of B to form one compound, and with 14 to form another, we are directed by some authors to take the smallest combining proportion of one body as representative of the elementary particle or atom of that body. Now it must be obvious to any one of common reflection, that such a rule will be more frequently wrong than right. For, by the same rule, we must consider the first of the combinations as containing 1 atom of B, and the second as containing 2 atoms of B, with 1 atom or more of A; whereas it is equally probable by the same rule, that the compounds may be 2 atoms of A to 1 of B, and 1 atom of A to 1 of B respectively; for, the proportions being 10 A to 7 B (or, which is the same ratio, 20 A to 14 B), and 10 A to 14 B, it is clear by the rule, that when the numbers are thus stated, we must consider the former combination as composed of 2 atoms of A and the latter of 1 atom of A, united to 1 or more of B. Thus there would be an *equal* chance for right or wrong. But it is possible, that 10 of A, and 7 of B may correspond to 1 atom A, and 2 atoms B; and then 10 of A, and 14 of B, must represent 1 atom A, and 4 atoms B. Thus it appears the rule will be more frequently wrong than right. It is necessary not only to consider the combinations of A with B, but also those of A with C, D, E, &c., as well as those of B with C, D, E, &c., before we can have good reason to be satisfied with our determinations as to the *number* of atoms which enter into the various compounds. Elements formed of azote and oxygen appear to contain portions of oxygen, as the numbers 1, 2, 3, 4, 5, successively, so as to make it highly improbable that the combinations can be effected in any other than one of two ways. But in deciding which of these two we ought to adopt, we have to examine not only the compositions and decompositions of the several compounds of these two elements, but also compounds which each of them forms with other bodies. I have spent much time and labour upon these compounds, and upon others of the primary elements, carbon, hydrogen, oxygen, and azote, which appear to me to be of the greatest importance in the atomic system; but it will be seen that I am not satisfied on this head, either by my own labour or that of others, chiefly through the want of an accurate knowledge of combining proportions.'"

This extract proves that Dalton, at the time of his "matured views and final teaching," in the year 1827, was unable to determine, by the help of his atomic theory, *how much of any single element constituted a single combining proportion.* Thirty years, fruitful in chemical discoveries, have since elapsed. But the disciples of Dalton are, at this time, as unable as was the philosopher himself, from the beginning to the end of his career, to determine the atomic weight of any single element by the help of the atomic theory. The defect is a radical one; and a "fixed law," affecting "to regulate combination in multiple proportions," instituted in virtue of a theory which cannot distinguish multiple proportions from single proportions, can only be regarded as a house built upon shifting sands, liable to be moved hither and thither with every wave of adverse doctrine.

RELATION OF THE ATOMIC WEIGHTS OF ELEMENTS TO THE SPECIFIC GRAVITIES OF THEIR GASES.

Among the methods that have been suggested for determining how much of an element constitutes a combining proportion, the one which is apparently least liable to error, is that which considers the specific gravities of elementary gases to be the expression of their combining proportions. Upon that idea,

the atomic weight of oxygen is = 16
that of hydrogen is = 1
" chlorine is = 35·5
" nitrogen is = 14

It was pointed out by Gay-Lussac in the year 1809, that the combining weights of the elements which produced gases, bore a relation to the weights of single volumes of gases, so that combination actually took place either between even volumes of gases or between simple multiples of even volumes.

Thus nearly at the same time that Dalton *invented* the atomic theory, Gay-Lussac *discovered* this law of nature. Of these two things, Gay-Lussac's has proved to be by far the most beneficial.

The difference in value between the two systems is easily shown by a few examples. One volume of hydrogen and one volume of chlorine produce two volumes, or one atom, of hydrochloric acid. This would agree with either theory.

Two volumes of hydrogen and one volume of oxygen form one atom of water, which in the state of gas measures two volumes.

Equal volumes of hydrogen and oxygen produce peroxide of hydrogen. Of course, equal volumes may signify $O^1 + H^1$, or $O^2 + H^2$. This compound is unknown in the state of gas.

We have seen that in the interpretation of the constitution of water, Dalton went upon no fixed ground. He considered it to be composed of one atom of each element, *because it was the only compound of oxygen and hydrogen with which he was acquainted.* Professor Miller's argument is scarcely more cogent. "Water," he says, "may be conceived to be a compound in which each separate particle of hydrogen is united with a single particle of oxygen; and peroxide of hydrogen would be represented as consisting of a combination of two particles of oxygen with each particle of hydrogen."

But if, as Berzelius originally suggested, we take a single volume of each of the four gases above named to represent a single combining proportion, we are freed at once from doubt and difficulty, at least as far as respects these four elements and their compounds. Thus:

$$\left.\begin{array}{ll}\text{One vol. of chlorine} & = \mathrm{Cl}\\ \text{One vol. of hydrogen} & = \mathrm{H}\end{array}\right\} = \mathrm{HCl} = \begin{array}{l}\text{Hydrochloric acid.}\\ \quad\text{2 volumes.}\end{array}$$

$$\left.\begin{array}{ll}\text{One vol. of hydrogen} & = \mathrm{H}\\ \text{One vol. of oxygen} & = \mathrm{O}\end{array}\right\} = \mathrm{HO} = \begin{array}{l}\text{Peroxide of hydrogen.}\\ \quad\text{volume unknown.}\end{array}$$

$$\left.\begin{array}{ll}\text{Two vols. of hydrogen} & = \mathrm{HH}\\ \text{One vol. of oxygen} & = \mathrm{O}\end{array}\right\} = \mathrm{HHO} = \begin{array}{l}\text{Water.}\\ \quad\text{2 volumes.}\end{array}$$

$$\left.\begin{array}{ll}\text{Two vols. of nitrogen} & = \mathrm{NN}\\ \text{One vol. of oxygen} & = \mathrm{O}\end{array}\right\} = \mathrm{NNO} = \begin{array}{l}\text{Protoxide of nitrogen.}\\ \quad\text{2 volumes.}\end{array}$$

$$\left.\begin{array}{ll}\text{One vol. of nitrogen} & = \mathrm{N}\\ \text{One vol. of oxygen} & = \mathrm{O}\end{array}\right\} = \mathrm{NO} = \begin{array}{l}\text{Deutoxide of nitrogen.}\\ \quad\text{2 volumes.}\end{array}$$

$$\left.\begin{array}{ll}\text{One vol. of nitrogen} & = \mathrm{N}\\ \text{Two vols. of oxygen} & = \mathrm{OO}\end{array}\right\} = \mathrm{NOO} = \begin{array}{l}\text{Peroxide of nitrogen.}\\ \quad\text{2 volumes.}\end{array}$$

The *point* to be observed here—the great point, the useful point, the deciding point, is, that we not only WEIGH the combining proportions, but we also MEASURE them, and we acquire by that means a security which Dalton's atomic theory can *never* afford us. If the resulting volumes of the compounds produced by the combination of these gases had been marked by regularity, the security afforded by this method of reasoning would no doubt have been perceived by chemists long ago; but the irregularity of the atomic measures of these compound gases obscured the view which chemists ought to have taken of their composition and components.

Consult the "Inquiry into the Causes which modify the Atomic Measure of Compound Gases," page 94.

Let us follow out the argument derived from the constitution of gases.

Only a few of the elements produce gases at the ordinary temperature of the air, and we must derive the atomic weights of the fixed or non-volatile elements by indirect processes. Yet the reference to the densities of the four gases, as fundamental authorities, is of the greatest importance. I frame upon it the observation that—

The combining proportion of any element is the quantity which is chemically equivalent to a single volume of hydrogen or of chlorine.

I take hydrochloric acid as the model of a chemical compound, or as I have called it, for shortness, a SALT. The formula is HCl, in which H and Cl represent two elements, each of which is separately replaceable by other elements. To these two replaceable *halves* of a salt, whether simple or compound, I apply the term RADICAL: in this example, H is the basic radical and Cl is the acid radical. If Cl is replaced by Br, we procure the salt HBr; if replaced by I, we procure the salt HI. The quantity of Br which replaces 35·5 parts of Cl weighs 80: the quantity of I weighs 127. If these quantities of Br and I are raised by heat into vapour until they measure as much as one volume of chlorine, the specific gravities of the vapours become as follow:

$$Cl = 35{\cdot}5;\ Br = 80;\ I = 127.$$

Consequently, these replacements confirm the accuracy of the rule, and fix the atomic weights of Br and I. On the other hand, if we replace the basic H in HCl by a metal, as by potassium, barium, silver, &c., we produce KCl, BaCl, AgCl, &c., and these quantities of metals combine equally well with the equivalent quantities of Br and I, to produce the neutral salts KBr, KI, BaBr, BaI, and AgBr, AgI; consequently, the quantities K, Ba, and Ag are the equivalents of H.

Proceeding in this manner, we gradually discover how much of each known element is the equivalent either of H^1 or Cl^1. The quantities thus determined are quoted in the Table which is printed at page 28, and which I take the liberty to call here, a Table of *Simple Radicals*. In the course of this proceeding, experiment develops the peculiarity, that certain metals possess the power to form *two simple radicals* which differ from one another in weight, but not in their chemical equivalency, each being able to replace H^1 and to neutralise Cl^1, Br^1, or I^1, and to produce a series of neutral salts, equivalent to one another in chemical power, but possessed of entirely different physical properties. Thus *iron* can produce a radical the weight of which is 28, and another, the weight of which is 18⅔, and these two radicals produce two extensive series of salts, which differ greatly in their properties, but only in their composition to the extent that 28 by weight of iron in one salt is replaced by 18⅔ of iron in the other, all other elements in the salts remaining the same. From the fact that these radicals produce salts that are perfectly and characteristically distinct from one another, I assume that the radicals themselves, though both produced by iron only, are perfectly different radicals. This argument is pursued at page 32, and I need not repeat it.

On the Daltonian theory, this parallelism in the sets of salts is not acknowledged to exist. Instead of it, a triplication is made of all the ingredients of one of the sets of salts, and the triple atoms are in each salt divided into an imaginary conglomeration of three atoms of "acid" and a "base" consisting of two atoms of metal and three atoms of oxygen, with which base the three atoms of acid are assumed to be combined. I have given an example of such salts at page 37. These complex salts are taken under the especial patronage of the law of combination in multiple proportions. They are commonly called salts of the sesquioxides, and their assumed composition is, without exception, imaginary and unreal.

The formula which I have adopted as the model of *a salt*, namely, HCl, is of great importance as regards organic compounds. I have shown that a vast number of organic compounds may be arranged in three groups:

A, *Basic Radicals*. B, *Acid Radicals*. C, *Salts*.

The basic radicals are equivalent to H, or a single volume of hydrogen; the acid radicals are equivalent to Cl, or a single volume of chlorine; the salts are equivalent to HCl, or to two volumes of hydrochloric acid: the evidence in support of these facts is given in the Table of Gases at page 49, and in the commentary which follows it. This evidence is abundant and conclusive. It proves that a radical measures one volume, and that it is of no importance as respects its measure whether a radical is simple or compound, whether it is oxidised or not oxidised. In short, it proves that one volume is the measure of a chemical equivalent, an acting quantity, a combining proportion, or an atom, give it what name you please, and therefore that one volume of an elementary gas is the quantity with which we may begin to construct our Table of Atomic Weights. The entire set of laws which are founded on the "atomic theory" are utterly insignificant, when compared with the results which thus naturally flow from Gay-Lussac's discovery respecting the combination of gases, and Berzelius's perception of its utility.

The discovery of the fact that radicals of every description are the equivalents of H^1 and Cl^1, and that two radicals complete a salt, whether oxygen is present or not, reduces the theory of salts to great simplicity, and goes far to obliterate the needless and absurd distinction which is usually made between inorganic chemistry and organic chemistry.

I need scarcely refer in this summary to matters of detail that have been amply developed in the article on the gases, such as the fact, that oxygen, carbon, sulphur, and radicals with an even number of atoms of hydrogen, measure nothing in gaseous salts; nor to any other of the peculiarities of the elements of gases, the elimination of which has enabled me to give to the theory of gases a useful degree of exactness. See page 108.

If the law of combination in multiple proportions was well founded, and could explain anything, it might be useful in organic chemistry to explain the production of complex organic radicals. Let us see how it helps us there. Turn to page 525, and look down Group A. What does the law of combination in multiple proportions teach us in reference to the radicals which are formulated in that column? Reading the Table, in accordance with this law, we may say—"One atom of carbon combines with three atoms of hydrogen to form one atom of methyl. Twenty-seven atoms of carbon combine with fifty-five atoms of hydrogen to form one atom of ceryl. Thirty atoms of carbon combine with sixty-one atoms of hydrogen to form one atom of myricyl." That is the teaching of the law of combination in multiple proportions! Can any human being believe such statements to be true? What kind of "affinity" is it which induces 30 atoms, all alike, to combine with one another into a clump, which induces 61 other atoms, also all alike, and in the presence of 30 different atoms, to combine with one another into another clump, and which then induces the two clumps to combine into one compound?

I confess, that this doctrine of combination in multiple proportions is beyond my powers of comprehension, and I cast it aside as a useless incumbrance. I do not believe that the radicals of Group A, page 525, are in any case formed by the direct combination of all their carbon with all their hydrogen. On the contrary, I believe that the radicals of this group, like those of all other groups, are built up progressively by the method which I have described in the last section. The evidence in favour of this supposition is the fact, that at each step of the progression, a definite radical is produced which possesses an ascertainable individuality.

Thus, H is a radical = Hydrogen.
$C + H$ is a radical = CH, Formyl.
$CH + H$ is a radical = CH^2, Vinyl.
$CH^2 + H$ is a radical = CH^3, Methyl.

Then, in another series we have

$$H+CH^2 = CH^3\text{, methyl.}$$
$$CH^3+CH^2 = C^2H^5\text{, ethyl,}$$
$$C^2H^5+CH^2 = C^3H^7\text{, propyl, and so on to}$$
$$C^{29}H^{59}+CH^2 = C^{30}H^{61}\text{, myricyl.}$$

In this process of construction, everything goes on step by step, and every step is of use. There is no evidence of the occurrence of those monstrous jumps of one mighty block of atoms to join another mighty block, which the law of combination in multiple proportions calls upon its votaries to credit.

When a galvanic circuit shall be found to require 30 zincodes and 61 platinodes, and shall be able to decompose an atom of myricyl in such a manner as to throw off 30 atoms of carbon at the zincodes and 61 atoms of hydrogen at the platinodes, and shall thereby give us some reason to believe in the possibility of "*decomposition* in multiple proportions," it will be time to begin to believe in the assumed fact of "*combination* in multiple proportions;" but there is no necessity to adopt this belief, till we have witnessed the performance of that experiment.

The Evidence of Electrolysis in favour of the Radical Theory.

As the terms employed by writers on electro-chemistry differ greatly, I take the liberty to prefix a list of synonyms.

Negative Pole; − pole; cathode; platinode; negative electrode.
To this pole go Hydrogen, Metals, Alkalies.

Positive Pole; + pole; anode; zincode; positive electrode.
To this pole go Oxygen, Chlorine, Acids.

A. MAGNUS'S RESULTS.

An interesting series of "electrolytic researches" has just been published by Professor G. Magnus (*Poggendorff's Annalen der Physik und Chemie*, No. 9, 1857, Band cii.), from which I extract the following 12 results; referring to the original essay for details.

1. For 1 equivalent of oxygen disengaged [in the voltameter], when cuprous chloride is acted on, 2 equivalents of copper are deposited.

2. From stannous chloride, Sn+Cl, for 1 equivalent of oxygen, 1 equivalent of tin. and as [illegible]

[illegible] that [illegible]

3. From stannic chloride, $Sn+2Cl$, for 1 equivalent of oxygen, half an equivalent of tin.

Hence, an atom of stannous chloride requires for its decomposition half as much electrical power as an atom of stannic chloride.

4. When the current went from the voltameter first through cupric sulphate and then through cuprous chloride, twice as much copper was deposited in the latter as in the former.

5. There is no evidence in favour of Daniell's supposition of the decomposability of $CuO+SO^3$ into $Cu+SO^4$.

6. When an aqueous solution of pure crystallised iodic acid is acted upon, 1 equivalent of iodine is deposited on the negative electrode and 5 equivalents of oxygen are set free on the positive electrode.

7. It requires five times the electric power to decompose an atom of iodic acid $= I + O^5$, that it requires to decompose an atom of water $= H + O$.

8. The same electric power is required to separate the same quantity of oxygen from iodic acid and sulphuric acid, while for H^1 disengaged by the sulphuric acid only $I\frac{1}{5}$ is deposited by the iodic acid.

9. To decompose an atom of ferric sulphate $= Fe^2O^3 + 3SO^3 + Aq$ into ferrous sulphate $2(FeO + SO^3)$ and into oxygen O, and sulphuric acid SO^3, it requires the same power as to decompose an atom of water $H + O$, and also the same power as to decompose $FeO + SO^3$ into iron on the one side, and oxygen and sulphuric acid on the other.

10. The same power is required to separate a simple substance from a binary compound as is required to separate it from a complex saline compound.

11. This result may present a difficulty to chemists, who can only conceive the decomposition of a salt to be into an acid and a base; for, according to this view, the power which is required to decompose the oxide must also be strong enough first to separate the oxide from the acid, and then to decompose the oxide. But this difficulty falls away if we consider the galvanic decomposition to be *a distributive action of the electricity* (eine vertheilende Wirkung der Electricität).

12. How greatly the atoms which are equivalents in galvanic action differ from chemical atoms is shown by the following examples:

Chemical Atoms.	Galvanic Equivalents.	
$H + O$	$H + O$	
$I + 5O$	$\frac{1}{5}I + O$ ×	
$CuO + SO^3 + 5Aq$	$CuO + SO^3 + 5Aq$	
$Cu + Cl$	$Cu + Cl$	Cu Cl
$2Cu + Cl$	$2Cu + Cl$	Cu
$Sn + Cl$	$\frac{1}{2}Sn + Cl$	Sn Cl
$2Sn + Cl$	$Sn + Cl$	Sn Cl

[illegible] and the [illegible]

B. FARADAY'S RESULTS.

13. "Electrolytes must consist of two ions."

14. "There is but one electrolyte, composed of the same elementary ions, at least such appears to be the fact, dependent upon a law, that only single electro-chemical equivalents of elementary ions, can go to the electrodes and not multiples."

15. "Electro-chemical equivalents coincide, and are the same with ordinary chemical equivalents."

16. "A very valuable use of electro-chemical equivalents will be to decide, in cases of doubt, what is the true chemical equivalent, or definite proportional or atomic number of a body; for I have such a conviction that the power which governs electro-decomposition and ordinary chemical attraction is the same, and such confidence in the overruling influence of those natural laws which render the former definite, as to feel no hesitation in believing that the latter must submit to them also. Such being the case, I can have no doubt, that assuming hydrogen as 1, and dismissing small fractions for the simplicity of expression, the equivalent number or atomic weight of oxygen is 8, of chlorine 36, of bromine 78·4, of lead 103·5, of tin 59, &c., notwithstanding that a very high authority doubles several of the numbers."

17. "The equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity . . . . . or, if we adopt the atomic theory or phraseology, then the atoms of bodies have equal quantities of electricity naturally associated with them. But I must confess I am jealous of the term atom; for though it is very easy to talk of atoms, it is very difficult to form a clear idea of their nature, especially when compound bodies are under consideration." Henry's *Memoirs of Dalton*, page 106.

C. GMELIN'S SUMMARY.

18. An electric current decomposes an atom of an oxygen salt in the same time as it decomposes an atom of water or chloride of lead.

19. When sulphate of soda is decomposed—it is found that the volume of detonating gas collected in the voltameter is equal to the volume of hydrogen obtained in the negative division of the decomposing apparatus together with that of the oxygen evolved in the positive division,—and that for every 9 parts (one atom) of water decomposed in the voltameter, 32 parts (one atom) of soda are set free in the negative, and 40 parts (one atom) of sulphuric acid in the positive division.

20. If the voltameter consists of fused chloride of lead, then an atom of lead is deposited for every atom of sulphate of soda, or sal-ammoniac, or chloride of sodium, which is decomposed in the cells.

21. These experiments are favourable to the supposition that the oxygen-salts should be regarded as compounds of metals with the so-called salt-radicals, — *e.g.*, sulphate of soda not as NaO,SO^3, but as Na,SO^4; and that the same quantity of electricity which serves to separate an atom of oxygen, chlorine, or iodine, from an atom of hydrogen, or a metal, is likewise exactly sufficient to separate an atom of SO^4, or any other compound salt-radical from an atom of metal.—*Daniell.*

22. Matteucci obtained the same results by subjecting other salts to similar treatment. For every atom of water decomposed in the voltameter he obtained from the saline solution 1 atom of hydrogen gas, 1 atom of oxygen, 1 atom of base, and 1 atom of acid.

23. The theory which regards sulphate of soda as Na,SO^4 certainly affords the simplest explanation of its electrolysis. Since, however, many weighty reasons may be urged against the adoption of this hypothesis, the following explanation may for the present be admitted. Sulphate of soda is NaO,SO^3; decomposition by the electric current is exerted only on the soda (since, by Faraday's law, SO^3 is incapable of direct decomposition). Sodium separates at the negative pole, where it decomposes water and yields soda and hydrogen gas. The oxygen which was combined with the sodium is transferred, together with the sulphuric acid, to the adjacent atom of sodium. An atom of oxygen is set free at the positive pole, and since the sodium which was combined with it goes towards the negative pole, the sulphuric acid is set free by secondary action, or rather it passes from its state of combination with soda into that of combination with water.

24. In the case of sulphate of copper, &c., similar actions take place, excepting that the metal liberated by the current does not decompose water.

25. The decomposition of oxygen-salts of ammonia is most satisfactorily explained by adopting the ammonium theory of Berzelius, according to which, sulphate of ammonia, for example, which always contains water, is to be regarded as sulphate of oxide of ammonium (NH^4O,SO^3). The electric current decomposes the oxide of ammonium, just as it does a metallic oxide, into oxygen and ammonium, and the latter is resolved into hydrogen gas which escapes, and ammonia which remains in solution. According to this view, the direct action of the electric current is confined to the decomposition of metallic oxides, and the transference of the acid from the decomposing oxide to the water is merely a consequence of this action. (Hess's Observations on Daniell's Theory, in *Pogg. Ann.*, 53, 505). Gmelin's *Handbook of Chemistry*, i. 460.

D. Particular Facts.

26. It is clearly proved by experiment that for every 32 grains of zinc which is dissolved in any one cell of the battery, 9 grains of water are decomposed in the voltameter.—*Miller.*

27. If the current is made to pass first through fused iodide of lead, and then through fused chloride of tin, for each 32 grains of zinc dissolved in any one cell of the battery, 104 grains of lead, and 59 grains of tin will be separated on the respective platinodes, whilst 126 grains of iodine, and 36 grains of chlorine will be evolved on the respective zincodes.—*Miller.*

28. When starch which contains both iodine and bromine is subjected to the action of the current, the mixture becomes blue at the negative pole and orange-coloured at the positive pole, showing that iodine is transferred to the former and bromine to the latter.—*De la Rive.*

29. When dilute phosphoric acid is acted upon, and the oxygen and hydrogen are collected apart, it is found that while one atom of water is decomposed, only from one-fifth to one-fourth of an atom of phosphoric acid is carried over to the positive pole.—*Daniell.*

30. When hydriodic acid is electrolysed, hydrogen goes to the negative pole, and iodine and oxygen to the positive pole.—*Matteucci.*

31. Aqueous solution of iodide of potassium yields iodine at the anode, potash and hydrogen gas at the cathode.—*Faraday.*

32. Fused protochloride of tin is resolved into metallic tin and bichloride of tin, the latter escaping in vapour.—*Faraday.*

33. Aqueous solution of sal-ammoniac is resolved into chlorine at the positive pole and hydrogen and ammonia at the negative pole.—*Hisinger and Berzelius.*

34. Solution of common salt gives chlorine at the positive pole, hydrogen gas and soda at the negative pole.—*Higgins and Draper.*

35. Hydrate of potash yields oxygen gas at the anode, and at the cathode hydrogen gas and potassium.—*Davy.*

APPLICATION OF ELECTROLYTIC FACTS TO THE SUPPORT OF THE RADICAL THEORY.

I proceed to show that these electrolytic facts are in accordance with the radical theory, and in particular with the following axioms:—

1. A salt is a compound of two radicals, simple or compound, with or without oxygen.

2. Water is a salt, whose constitution is represented by the formula $H+HO$.

3. All combination is binary. One basic radical combines with one acid radical.

4. Combination in multiple proportions never takes place.

5. Chemical radicals are the same as galvanic equivalents.

In the following explanations, I take the facts in the order of the foregoing list. The symbols have now the values given at page 28.

1. Cuprous chloride, CuCl, gives Cu, with $\frac{1}{2}$ O in the voltameter.

Because Cu is the basylous atom = 64 combined with Cl. Both Cu and Cl are equivalent to H. Consequently $\frac{1}{2}$(HHO) is decomposed in the voltameter. If HHO were set free in the voltameter, that is to say, 2 parts or 2 volumes of hydrogen, and 16 parts or 1 volume of oxygen, the equivalents of HH, namely, ClCl and CuCu, must be set free in the cells. Magnus's "1 equivalent of oxygen," signifies 8 by weight, or $\frac{1}{2}$ volume of gas, so that if the equivalent of O is doubled, the equivalent of the deposited metals must also be doubled. On this point, consult No. 16, page 556.

2. Stannous chloride, SnCl, gives Sn for $\frac{1}{2}$ O. Because Sn is the basylous atom = 59, combined with Cl. Both atoms = H. Hence $\frac{1}{2}$(HHO) is decomposed.

3. Stannic chloride, SncCl, gives Snc or $\frac{1}{2}$ Sn, for $\frac{1}{2}$ O. Because Snc is the basylic atom = 29·5, combined with Cl. Both atoms = H. Hence $\frac{1}{2}$(HHO) is decomposed.

Magnus's idea that the atom of stannous chloride requires for its decomposition half as much electrical power as the atom of stannic chloride is a fallacy. If Cl is put as the standard, the same power separates it from each salt, but with the deposition of Cu in one case, and Cuc in the other, the former radical being twice as heavy as the latter.

4. When cupric sulphate = CucSO^2 and cuprous chloride = CuCl are acted on by the same current, the first gives Cuc = 32, and the second gives Cu = 64, because both of these are radicals of the same chemical and voltaic equivalence.

5. Read Gmelin's summary of facts and opinions as to Daniell's Theory, Nos. 18 to 25.

I do not know in what manner the oxygen of a salt is divided between the basic radical and the acid radical, and the whole series of electrolytic researches gives no conclusive results on this point.

When sulphate of copper = Cuc,SOO, which consists of two radicals with two atoms of oxygen, is decomposed in the presence of water, I apprehend that hydrated sulphuric acid is instantly constituted at the cost of an atom of water; thus:

$$\begin{array}{ll}\text{Salt}\;\;. & \left\{\begin{array}{r}\text{Cuc,SOO}\\ \text{Cuc,SOO}\end{array}\right. \\ \text{Water} & \qquad\text{HHO}\end{array}\left.\vphantom{\begin{array}{c}a\\a\\a\end{array}}\right\} = \left\{\begin{array}{r}\text{Cuc} + \text{H,SOO}\\ \text{Cuc} + \text{H,SOO}\\ \text{O}\end{array}\right.$$

According to this equation, 64 parts of copper are deposited while 16 parts of oxygen are disengaged, which agrees with the statical results. The reason that two atoms of the copper salt are decomposed is, that water contains two atoms of hydrogen, and demands two atoms of sulphur with which to combine. See No. 16, page 556.

The passage of the electric current through a solution of sulphate of copper, may be represented thus:

A. *Before the current passes.*

	CucSOO	CucSOO	CucSOO	
– Pole	CucSOO	CucSOO	CucSOO	+ Pole.
			HHO	

B. *After the current passes.*

	Cuc	SOOCuc	SOOCuc	SOO		
– Pole	Cuc	SOOCuc	SOOCuc	SOO		+ Pole.
				HH	O	

Before the current passes, (A.), the atoms of sulphate are supposed to be in contact with water, ready to act in case of need, which I take it we must admit to be the constant duty of the water of a solution. After the current passes (B.), an atom of oxygen is given off at the positive pole, two atoms of hydrated sulphuric acid are deposited there, and simultaneously two cupric atoms are deposited at the negative pole. The electric power is transferred through the solution in the manner shown by the diagram.

In this explanation, I have supposed that the cupric sulphate is Cuc + SOO; let us see how it would act if its composition were CucO + SO.

A. *Before the current passes.*

	CucOSO	CucOSO	CucOSO	
– Pole	CucOSO	CucOSO	CucOSO	+ Pole.
			HHO	

B. *After the current passes.*

	Cuc	OSOCuc	OSOCuc	OSO		
– Pole	Cuc	OSOCuc	OSOCuc	OSO		+ Pole.
				HH	O	

There is no effect represented here which helps to decide the question whether the oxygen of a sulphate is entirely combined with the sulphur, or divided equally or unequally between the sulphur and the metal. The movements of oxygen are too subtle for detection either by chemical reactions or electrolysis.

6. When a salt which contains iodine as its negative radical without oxygen, is electrolysed, the iodine is deposited on the positive pole; see iodide of potassium (27 and 31) and hydriodic acid (30); but when iodic acid (H,IO^3) is electrolysed, the iodine is deposited on the negative pole, and the oxygen is given off on the positive pole.

7, 8. The disengagement of O^5 from diluted sulphuric acid leaves the sulphuric acid in its original condition, so that the O^5 come entirely from water, and must liberate H^{10}. The disengagement of O^5 from iodic acid leaves nothing but iodine, its hydrogen and oxygen being all disengaged; but since HIO^3 does not contain O^5, we must examine more closely what this reaction signifies:

$$\begin{matrix}\mathrm{HIOOO}\\\mathrm{HIOOO}\end{matrix} = \mathrm{I}^2 + \mathrm{HHO} + \mathrm{O}^5.$$

When this compound is exposed to electrolysis, I imagine that it gives off its oxygen atom by atom, producing a series of acids which may be represented by the following formulæ:

$$\begin{array}{l|l|l}
1. \left\{\begin{matrix}\mathrm{HIOOO}\\\mathrm{HIOO}\end{matrix}\right. + \mathrm{O}^1 & 3. \left\{\begin{matrix}\mathrm{HIOO}\\\mathrm{HIO}\end{matrix}\right. + \mathrm{O}^3 & 5. \left\{\begin{matrix}\mathrm{HIO}\\\mathrm{HI}\end{matrix}\right. + \mathrm{O}^5 \\
2. \left\{\begin{matrix}\mathrm{HIOO}\\\mathrm{HIOO}\end{matrix}\right. + \mathrm{O}^2 & 4. \left\{\begin{matrix}\mathrm{HIO}\\\mathrm{HIO}\end{matrix}\right. + \mathrm{O}^4 & 6. \left\{\begin{matrix}\mathrm{I}\\\mathrm{I}\end{matrix}\right. + \mathrm{HHO}
\end{array}$$

By five successive operations, each equivalent to the decomposition of an atom of water, and each therefore yielding O^1, it gives off in all O^5. Arrived at this point, the last O and the two atoms of H combine together, and the iodine is finally isolated. It is easy to understand, that as the iodine is deposited on the negative pole, the liberated oxygen must act there upon the water, and cause a corresponding reaction at the positive pole. Every O^1 lost by the iodic acid takes H^2 from the water at the negative pole, and therefore throws off O^1 at the positive pole. The correspondence of the decomposition of one atom of iodic acid with the disengagement of O^5 from sulphuric acid is clear enough, but it remains equally clear that the acid radicals of iodic and sulphuric acid are each one radical, and that each effects the decomposition of 5HHO.

9. I conceive this reaction to take place as follows:

$$\begin{matrix}\left\{\begin{matrix}\mathrm{FecSO}^2\\\mathrm{FecSO}^2\\\mathrm{FecSO}^2\end{matrix}\right\}\\\left\{\begin{matrix}\mathrm{FecSO}^2\\\mathrm{FecSO}^2\\\mathrm{FecSO}^2\end{matrix}\right\}\\\mathrm{H,HO}\end{matrix} = \begin{matrix}\left\{\begin{matrix}\mathrm{FeSO}^2\\\mathrm{FeSO}^2\\\mathrm{H\ SO}^2\end{matrix}\right\}\\\left\{\begin{matrix}\mathrm{FeSO}^2\\\mathrm{FeSO}^2\\\mathrm{H\ SO}^2\end{matrix}\right\}\\\mathrm{O}\end{matrix}$$

Under the action of the electric current, which decomposes an atom of water and sets free H^2, the ferric atoms of these sulphates become converted into ferrous atoms. Six ferric atoms produce four ferrous atoms, and set free $SO^2 + SO^2$ to take up the free H^2 and produce two atoms of hydrated sulphuric acid. The separation of H^2 from water sets O^1 free. Extensive as this reaction appears in the diagram, the electrolytic action takes place only upon one atom of HHO, and therefore corresponds with HHO in the voltameter. The presence of the basic hydrogen thus set free, is the predisposing cause of the reduction of the ferric atoms to ferrous atoms. I have fully explained the nature of this operation at pages 34 and 310 in this work.

The reduction of ferrous sulphate to iron, oxygen, and sulphuric acid, referred to in 9 as being effected by the same amount of electric power as the decomposition of H + HO, may be explained as follows:

$$\begin{array}{lcl} FeSO^2 + H & & Fe + HSO^2 \\ FeSO^2 + H & = & Fe + HSO^2 \\ \qquad\quad\;\; O & & \qquad\quad\;\; O \end{array}$$

Here again the effect is practically produced by the electro-decomposition of one atom of water.

10. The statement made at this number is true within certain limits, but not in an absolute sense. *One unit* of electric power decomposes one equivalent of an iodide and liberates one atom of iodine,—see 27, 31—whereas *five units* of electric power are demanded to decompose one equivalent of hydrated iodic acid, and liberate one atom of iodine,—see 6, 7, 8.

The statement is probably true of all salts that contain TWO RADICALS *with no oxygen, or with* O^1, *or with* O^2, but not with O^3; for the salts of iodine with O^3, just referred to, and those of phosphorus with O^3,—see 29—both require additional force. The uniformity of the action upon salts that contain O^0, O^1, O^2, depends upon the contemporaneous reaction on one atom of water H + HO; the special results in each case varying according to the individual properties of the radicals submitted to electrolysis; such as the power of the separated metal to remain metallic, as copper, or to form a hydrated alkali, as potassium, or that of the acid radical to fly off in gas as chlorine, or to remain in the liquid as hydrated acid, like sulphuric acid.

11. The difficulty which Magnus alludes to in this number, is for me non-existent. Every *base* and every *acid* is for me a SALT. All these three classes of compounds contain on the radical theory two radicals, and are subject to decomposition by the same amount of electric power, provided their quantum of oxygen presents no hindrance. But if I felt a difficulty on this point, and required an explanation, I should be dissatisfied with that which is given by Magnus; because I am unable to comprehend how "the same power" can perform distributively twice the work that it can perform collectively.

12. Magnus's conclusion, that "*galvanic equivalents are not the same as chemical atoms*" is a fallacy, which arises from the reasonings prompted by his atomic weights (viz., O = 8, water = H + O, &c.) and which disappears when the equivalents are adjusted to suit the atomic weights of the radical theory. Thus—

Water should be = H,HO.
Hydrated iodic acid = H,IO^3

Cupric sulphate = $\mathrm{CucSO^3}$
Cuprous chloride = CuCl
Cupric chloride = CucCl
Stannous chloride = SnCl
Stannic chloride = SncCl.

The explanations which I have given prove that the chemical and galvanic atoms are perfectly equivalent. Be it remarked, however, that the chemical equivalents are not *atoms* according to the common scale of atomic weights, but *radicals* in accordance with the radical theory, which acknowledges that both tin and copper make two different radicals, each of which is the equivalent of an atom of hydrogen, even in the electric current.

13. This first law of electrolysis, as laid down by Faraday, seems to be true, and to be destructive of the law of combination in multiple proportions; for if chemical and electrical action is *the same*, how can we logically admit that chemistry can combine together multiple proportions which electricity cannot separate?

14. This result must be compared with the results obtained by Magnus, such as the electrolysis of the compounds—

$\mathrm{Cu\ Cl}$	$\mathrm{Sn\ Cl}$
CucCl	SncCl

These results seem to be in opposition to the law which is here laid down by Faraday, but they agree perfectly well with the theory that the basylous and basylic atoms are different radicals produced by the same element, and act severally as elementary ions.

15. Electro-chemical equivalents agree with radicals.

16. I agree with Faraday's general principle, but not with all the atomic numbers which he has deduced by means of it. Those of chlorine, bromine, and lead I agree to. That of tin represents the stannous radical, and must be coupled with another to represent the stannic radical. Faraday's experiment (32) is not adverse to this proposal. He found that SnCl was resolved by electrolysis into $\mathrm{SncCl} + \mathrm{Snc}$, namely, the combined action of heat and electricity splits Sn into $\mathrm{Snc} + \mathrm{Snc}$, half the metal remains behind and the volatile SncCl flies off in vapour. My chief objection lies to Faraday's number for oxygen = 8, which is only half what it ought to be. It is no doubt true that *half a volume of oxygen gas* is separable in electrolysis, with *one volume of hydrogen gas*; but it is equally true, that one volume of oxygen gas is separable with two volumes of hydrogen; and the law of galvanic equivalency is sufficiently obeyed, if it is shown, that for every volume of oxygen which is disengaged, there is a simultaneous disengagement of two volumes of hydrogen; for the electrolysis of water into $\mathrm{HH} + \mathrm{O}$, that is to say, into two volumes of hydrogen and one

volume of oxygen, is the product of TWO *electrolytic operations;* the first of which separates H + HO into H and HO, while the second separates HO into H and O. It is a consequence of this twofold electrolysis, that *the same current* which decomposes 18 parts of water in the voltameter, decomposes two atoms of any normal salt upon which it is made to act, and sets free four radicals, two of them basic and two acid: thus, the decomposition of 18 parts of HHO in the voltameter is accompanied by the simultaneous

Deposition of	*and Separation of*	*From*
Cu + Cu = 128 parts.	Cl + Cl	2Cu Cl = No. 1.
Cuc + Cuc = 64 parts.	$SO^2 + SO^2$	$2CucSO^2$ = No. 4.
Sn + Sn = 118 parts.	Cl + Cl	2Sn Cl = No. 2.
Snc + Snc = 59 parts.	Cl + Cl	2SncCl = No. 3.
Na + Na = 46 parts.	$SO^2 + SO^2$	$2NaSO^2$ = No. 19.

Thus, when the voltameter, or standard of electrolytic power, is the quantity of water that undergoes decomposition, there is, in all cases, for each HHO that is decomposed, or each O that is set free, a decomposition effected of two atoms of a normal salt, which sets free two positive radicals and two negative radicals, it being perfectly indifferent, as respects the electrolytic power, whether the positive radicals are of the basylous or the basylic description. If the reader prefers to have this result stated in the usual cabalistic language of chemists, I may say, that the same current can separate a greater quantity of metal from a "*protosalt*" than it can from a "*persalt*."

When the voltameter of a circuit contains a binary compound free from water, such as fused chloride of lead, then the current which decomposes one atom of the standard and liberates its two radicals, will also decompose one atom of any normal salt through which it passes; thus:—

$$\mathrm{Pb} + \mathrm{Cl} \left\{ \begin{array}{l} = \ \mathrm{Na,SO^2} \\ = \ \mathrm{ZH^4,Cl} \\ = \ \mathrm{Na,Cl} \end{array} \right\} = \text{No. 20.}$$

$$\mathrm{Pb} + \mathrm{I} \ = \ \mathrm{Sn,Cl} \ = \text{No. 27.}$$

Hence it follows, that Faraday's laws of electrolysis agree precisely in *sense* with the radical theory, and differ only in the *form of expression* which was accommodated by him to the current views of chemists. If water is taken to be constituted of H + HO, and oxygen is fixed at 16, we still agree with Faraday's results.

17. Here, again, we have a law which is opposed, and justly opposed, to the law of combination in multiple proportions. If the equivalent radicals A. and B. contain equal quantities of electricity, that is to say, equal powers of chemical combination, it is impossible for

them to neutralise one another when presented for combination in such assortments as

$$A + 2B,\ A + 3B,\ A + 4B$$
$$2A + 3B,\ 2A + 5B,\ 2A + 7B.$$

See the quotation from Professor Miller, at page 537. So also the formation of the organic radicals $C^{30} + H^{61}$, $C^{30} + H^{59}$, &c., page 525, must be impossible. If we consider the nature of these examples, we must conclude that if the law of combination in multiple proportions is true, those of electro-chemistry must be false; for they are perfectly incompatible.

18. This observation agrees with No. 10 of Magnus's results, and needs no further remark.

19. The decomposition of sulphate of soda here described may be represented as occurring in a circuit, thus:—

A. *Before the current passes.*

	H HO	Na, SO^3	Na, SO^3	Na, SO^3	
– Pole	H HO	Na, SO^3	Na, SO^3	Na, SO^3	+ Pole.
				HHO	

B. *After the current passes.*

	H	HO Na	SO^3 Na	SO^3 Na	SO^3	
– Pole	H	HO Na	SO^3 Na	SO^3 Na	SO^3	+ Pole.
					HH	O

This scheme shows distinctly how it happens that one volume of oxygen is given off at the + pole, and two volumes of hydrogen at the – pole, and how, corresponding with these proportions of the two gases, we have two equivalents of hydrated sulphuric acid at the + pole, and two equivalents of hydrated soda at the – pole.

20. This agrees precisely with Faraday's proportions: 2 atoms of sulphate of soda = 2 atoms of lead = 2 atoms of chlorine = 18 parts by weight of water. See No. 16.

21. What Daniell and Gmelin call $NaSO^4$ is what I call $NaSO^3$. Daniell's experiment proves nothing respecting the distribution of the oxygen between Na and S. That puzzle still awaits a solution.

22. Numbers which corroborate those given in 19.

23 and 24. Already sufficiently explained at No. 5.

25. The first effect produced on an oxidised salt of ammonia would probably resemble that produced on a salt of soda. See 19. Hydrogen would escape, and we should have in solution the hydrate $ZH^4 + HO$. If the electrolytic action proceeded, the next decomposition would be into $ZH^3,H + H,HO$; namely, water would be separated, and ammonia produced. This may go off as gas, or finally be resolved into $N + H^3$.

26. The reaction $Zn + H,SO^2 = H + Zn,SO^2$ is equal to $\frac{1}{2}HHO$; or if we double the figures we have

$$\left.\begin{array}{l} Zn + H,SO^2 = H + Zn,SO^2 \\ Zn + H,SO^2 = H + Zn,SO^2 \end{array}\right\} = HHO \text{ in the voltameter.}$$

27. These quantities represent the weights of radicals, as already explained.

28. Another example of the separation of iodine at the negative pole. In 27 and in 30 it is separated at the positive pole. Hence, even energetic elements can act either as basic or as acid radicals, according to the force impressed upon them by other radicals with which they are in contact.

29. Compare this experiment with the note to No. 8.

30. Electrolysis of hydriodic acid = HI. The oxygen gas is, of course, derived from water, which is decomposed simultaneously. The quantity of oxygen increases with the dilution of the acid and the strength of the current. The quantity of hydrogen which is disengaged at the negative pole is always equal to that which is disengaged in the water voltameter; because HI is equal to $\frac{1}{2}H,HO$, and so far as water is concerned, H,HO in the solution is equal to H,HO in the voltameter.

31. Electrolysis of an aqueous solution of iodide of potassium:—

A. *Before the current passes.*

– Pole | H HO | K I | K I | K I | K I | + Pole.

B. *After the current passes.*

– Pole H | HO K | I K | I K | I K | I + Pole.

32. See No. 16.

33. Decomposition of sal-ammoniac:—

$$ZH^4Cl \text{ yields} \left\{\begin{array}{l} Cl \text{ at the + pole.} \\ \left.\begin{array}{c} ZH^3,H \\ H \end{array}\right\} \text{at the – pole.} \end{array}\right.$$

34. Electrolysis of common salt:—

$$\left.\begin{array}{r} Na,Cl \\ H,HO \end{array}\right\} \text{yield} \left\{\begin{array}{l} Cl \text{ at the + pole.} \\ \left.\begin{array}{l} Na,HO \\ H \end{array}\right\} \text{at the – pole.} \end{array}\right.$$

35. Decomposition of hydrate of potash (*Davy*):—

$$K,HO \text{ yields} \left\{\begin{array}{l} O \text{ at the + pole.} \\ \left.\begin{array}{l} K \\ H \end{array}\right\} \text{at the – pole.} \end{array}\right.$$

SUMMARY.—I consider the evidence that is afforded by these electrolytic experiments to be entirely in favour of the radical theory. Magnus's results prove that radicals, and not atoms, are the galvanic equivalents. The tendency of the whole of the experiments is to show, that H + HO is the true formula for water. With the aid of this formula every electrolytic experiment is easily and clearly explained. Without it, you must adopt Magnus's conclusion, that "galvanic equivalents differ from chemical atoms," and thus unsettle the electro-chemical theory, and settle nothing. The experiments of Faraday and Daniell distinctly agree with the radical theory. Those of Magnus are identified with it, and incompatible with any previous theory. The only ground upon which English chemists can persist in ascribing to water the formula HO, is, that they have been accustomed to do so for fifty years. That water is a binary compound of oxygen and hydrogen, was the first deduction from the Atomic Theory, and it has been a fruitful source of fallacies and difficulties during the entire period of its supremacy. There will be no simplicity in chemical formulæ, and no logic in chemical theories, until this Idol of Daltonism is overthrown.

Catalysis.

Chemical combinations and decompositions sometimes occur in the presence of substances which seem to cause these reactions, but which are not changed by them.

Some facts described in these pages may help to explain this mystery. 1. The element azote by producing an amidogen converts three radicals into one; by producing an ammonium, it converts five radicals into one. It can let free these radicals by combining with C^1 to produce an acid radical; and these changes can be reversed. 2. Certain metals produce two radicals. Thus Cu can become Cuc^2, and Cuc^2 can become Cu. Sn can become Snc^2, and Snc^2 can become Sn. Fe^2 can become Fec^3, and Fec^3 can become Fe^2. All these changes take place according to the amount of basic or acid power that is brought to bear upon the materials; such changes in the number of radicals, produce an enormous alteration in the saturating capacity of a given quantity of matter; and as it is possible that the acting substances may end as they began, a great effect is produced by a hidden cause.

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